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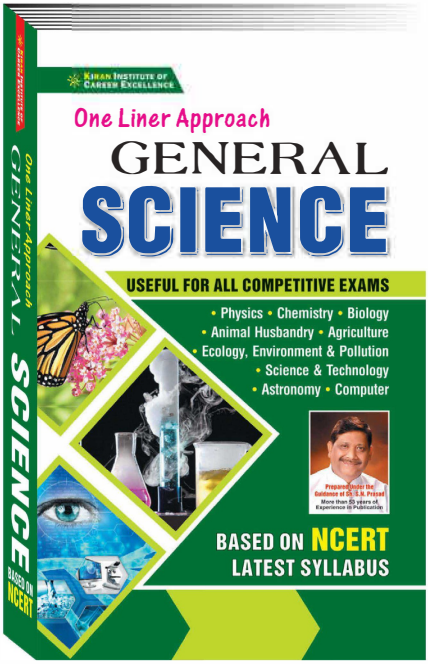

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To The Reader

It is indeed an enthusing experience to present a handy book **Kiran's One Liner Approach General Science** to our discerning readers. You are well abreast of the fact that questions based one General Science have a reasonable share in every competitive exam of today. More importantly its share is being enhanced gradually. One can't deny its importance even in Railway exams. A book that satiates the wide dimension of subject matter well suited to the needs of a wide variety of exams was eagerly felt by the community of true contenders. Our Team of learned authors also thought the same. This book has precisely been prepared after a sincere analysis of the questions of various competitive exams. The length of subject; standard of questions and their variety got a sincere attention. The book is reflection of modernity and essence of fundamentals. No doubt one liner approach gets its reflection in the presentation of this book. Believably , a student with a science background or without it will certainly extract advantage equally with smoothness.

It is well said, 'There is no sweet without sweat'. We , a firm believer of the above too, will assure you that with this edition in your hand you will definitely perspire less while making endeavour to achieve your desired goal i.e. cracking the examination in first attempt. Once you go through the edition attentively, you will not be knocking at the door of success but pushing it hard to open with a smile.

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The discernible reasons are:

- Very simple and lucid language used to express the fundamental and textual concepts.
- Wide variety of text covered and then compiled into one after analysis of question papers of more than 10 years from SSC to Railways, Banking, etc.
- Division of book into 5-Sections of Physical Sciences including Physics and Chemistry, Biological Sciences , Computers and never ceasing progress/inventions in the field of Science and Technology.
- Each of the 5-Sections divided into Sub-sections in the form of Units, well arranged in a sequential order from A to Z.
- Each Unit with well listed contents covered under its umbrella at the beginning engrossed in *Italics Font* to help you save time while

turning over the pages to look for a particular text.

- Each unit enriched and suspplemented with labeled Pictures, Tables, Flow Charts along with solved numerical problems wherever necessary realizing
- the value of picture/ diagram in proper comprehension of the text.
- the types of numerical based questions that had so far been asked in different spheres of examinations.
- Above all, the points of significance have been highlighted in red colour text, not to scare but draw attention, hence, minimizing any chance of overlooking the text.

With the above listed features and many more, the team of Co-authors wish to extend their gratitude to all the members of the **Kiran Institute of Career Excellence Pvt. Ltd.** , directly or indirectly involved in turning a dream into reality for students of diverse spheres , each with his own needs and requirements but the only goal to hit the bulls eye i.e. grab the 'Grand Success '.

In the end, the team also promises to look into suggestion deeply if any put forth by the reader for the betterment of this book and include the same in the forthcoming editions, rendering appreciation to improvement.

With Thanks.

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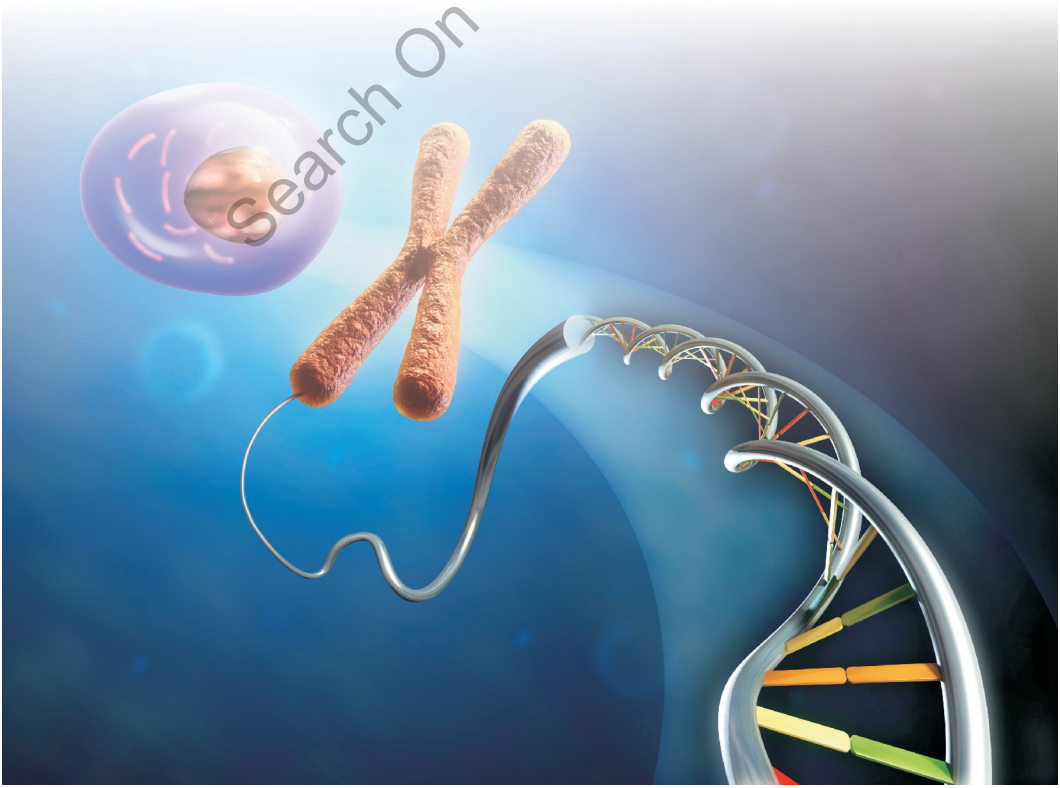

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UNIT-I

PHYSICS

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Chapter 1

PHYSICS AND DIFFERENT BRANCHES

Physics, different branches of physics and their significance in understanding natural phenomena and nature as a whole.

- **Physics :** The word 'physics' comes from the Greek word *phusike* meaning 'knowledge of Nature,' and in general, the field aims to analyze and understand the natural phenomena of the Universe.
- It involves the performing of experiments and their successive repetitions to formulate laws and explain how the universe works. These laws (such as gravity and Newton's laws of motion) are so thoroughly tested that they are accepted as 'truths,' and they can be used to help us predict how other things will behave.
- It is considered to be the most fundamental science. It provides a basis for all other sciences, without physics, one cann't have proper understanding of biology, chemistry or anything else.

BRANCHES OF PHYSICS

- **Classical Physics :** It's a branch of physics that mainly deals with the laws of motion and gravitation of Sir Isaac Newton and James Clark Maxwell's Kinetic theory and thermodynamics. Classical physics is mainly concerned with matter and energy. In classical physics, energy and matter are considered as separate entities.

  Acoustics, Optics, Classical mechanics and Electromagnetics are the traditional branches of classical physics. Moreover, any theory of physics, which is considered null and void in the modern physics, automatically falls under the realm of classical physics.
- **Modern Physics** : It is the branch of physics mainly concerned with the 'Theory of relativity' and 'Quantum mechanics'. Albert Einstein and Max Plank were the pioneers of modern physics. They were the first scientists who laid down the foundations of modern physics by introducing the theory of relativity and quantum mechanics respectively. In modern physics, energy and matter are not considered as separate entities, rather, they are considered as different forms of each other.
- **Nuclear Physics :** It is the branch of physics which deals with constituents, structure, behaviour and interactions of nucleons and atomic nucleius. It Is usually described as "the branch of physics in which the structure, forces and behaviour of the atomic nucleus

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are studied". In the modern age, it is used in power generation, nuclear weapons, medicines such as radio therapy, etc.

- **Atomic Physics :** It is the branch of physics which deals with the composition of an atom apart from the nucleus. It is mainly concerned with the arrangement and behaviour of electrons in the shells around the nucleus.
- **Geophysics :** It is the branch of physics which deals with the study of the earth. It is mainly concerned with the shape, structure and composition of the earth. It also studies the gravitational force, magnetic fields, earthquakes, magmas, eruption of volcanoes, etc. their causes and effects.
- **Biophysics :** It is described as the interdisciplinary study of biological phenomena and problems, using the principles and techniques of physics. Biophysics studies only the biological problems and structure of molecules in living organisms in light of the techniques derived from physics. One of the best achievements of biophysics is the structure of DNA (Deoxy-ribonucleic Acid) discovered by, X-ray Crystallography.
- **Mechanics :** It can be classical or modern.
- **Classical mechanics** deals with the laws of motion of physical objects and the forces that cause the motion,
- **Quantum mechanics** deals with the behaviour of the smallest particles, *i.e.* electrons, neutrons and protons. According to Encarta dictionary, "Quantum mechanics is the study evolved in an effort to explain the behaviour of atoms and subatomic particles, which do not obey the laws of classical Newtonian mechanics."
- **Statistical Mechanics** includes the discipline that attempts to relate the properties of macroscopic systems to their atomic and molecular constituents. It especially involves the distribution of energy among them with maximum usage of probability theory.
- **Theoretical physics** includes attempts to understand the world by making a model of reality, used for rationalizing, explaining and predicting physical phenomena through "physical theory".
- **Acoustics :** The word *acoustics* has been derived from a Greek word *akouen*, meaning *to hear*. Hence, acoustics is defined as a branch of physics, which studies how sound is produced, transmitted, received and controlled. It also deals with the effects of sounds in various mediums, *i.e.* gases, liquids and solids.
- **Optics :** It is the branch of physics, which deals with the propagation, behaviour and properties of light, a part of the electromagnetic spectrum that extends from X-rays to microwaves and includes the radiant energy that produces the sensation of vision.

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- **Thermodynamics :** It is the branch of physics, which deals with the study of heat and its relation with energy and work. According to National Aeronautics and Space Administration (NASA), USA, "Thermodynamics is the study of the effects of work, heat and energy on a system. It is only concerned with large-scale observations and their analysis".
- **Astrophysics :** The word *astrophysics* is a combination of two words-*astro* which means *star*, while the word *phisis* means *Nature.* Thus, astrophysics is defined as a branch of astronomy concerned with the study of the Universe, *i.e.* stars, galaxies and planets using the laws of physics.
- **Cosmology :** Cosmology, astrophysics and astronomy are the similar fields of study, however, cosmologists wonder particularly about the origins and the future of the universe. It deals with the universe as a whole phenomena such as the Big Bang, dark matter, black holes, wormholes, expansion of the known universe and a potential multiverse, these are the dominant areas of interest in cosmology.
- **Cryophysics (Cryogenics) :** It is also called as low temperature physics and generally pertains to temperatures below -150°C or -238°F (123 K) and how matter behaves to cold conditions. Cryogenicists tend to avoid using the standard temperature formats of Celsius and Fahrenheit but instead use Kelvin or Rankine scale which are considered to be on absolute scale. Cryobiology, cryosurgery, cryonics, cryogenics and cryoelectronics are the subspecialties of cryophysics.
- **Crystallography :** The study of crystallography explores atoms in their solid state of matter with particular focus in molecular and atomic structure. Previously, the study of the geometry of crystals in relation to their axes was necessary to shed light within this field. However, in recent years the development of x-ray diffraction allows a much greater insight into the axis and symmetry of crystals.
- **Electromagnetism :** There are four fundamental forces of nature which determine the interactions between matter and energy which include strong interaction, weak interaction, gravitational force and electromagnetic force. The scientists who specialize in electromagnetism investigate phenomena such as electrically charged particles, magnetic attraction and electromagnetic fields.
- **Electronics :** Electrical circuits, diodes, transistors, integrated circuits and vacuum tubes are all areas of interest for scientists fascinated by electronics. The flow of electrons along with a predesignated pathway to process information and generate signals in telecommunication has helped advance civilization, culture and knowledge of humanity in the modern era.

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- **Fluid Dynamics :** The mechanics of motion in fluids in both liquid and gaseous states is investigated in the studies of fluid dynamics. The sub-disciplines of hydrodynamics, relating to liquid in particular, and aerodynamics, its gas equivalent, are also considered to be natural sciences which help understand the interactions between energy and matter on the earth and throughout space.
- **Nanotechnology :** It refers to the ability to manipulate the properties of matter at the molecular, atomic and subatomic levels. The term nanoparticle is used to classify particle types that are between the size scale of 1 – 100 nanometre (1×10^{-9}m). Quantum mechanics theories play an integral role in the investigation of nanotechnology by providing insight into how atomic and subatomic particles interact with each other.
- **Particle Physics :** In recent times, particle physicists have made great strides in their research with the development of advanced technologies such as the large hadron collider developed by CERN. The ability to analyze detailed information by colliding particles together at the high rates of speed has led to the discovery of new types of particles previously theorized by physicists around the world. Research into particle physics has the potential to help scientists better understand the origins of our universe and the complexity of factors that govern the world we know.
- **Plasma Physics :** Plasma is the fourth state of matter which is characterized by heating gases to the point at which ionization occurs altering the number of electrons in the atoms (releasing electrons from the nucleus). Although we are typically taught that only 3 states of matter exist (solids, liquids and gases) yet ironically, plasma is the fourth and most common state of matter throughout the universe which is most commonly visible in the form of stars.
- **Meteorology :** It deals with the understanding of the dynamics of the Earth's atmosphere. Gravity, the Earth's spin, polarity, wind and temperature. They all play a crucial role in the investigation of physical and chemical phenomena in the atmosphere.

The above shows that of physics is inseparable from the study of nature in any form of rows the study of the Universe to a chemical reaction occuring in test tube or global climatic changes from global warming, melting of polar ice, acid rain and depletion of ozone layer. It's all because in physics, one studies both about matter in its varied forms and energy.

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Chapter 2

PHYSICAL QUANTITIES : S.I. AND DERIVED UNITS

PHYSICS

Fundamental units, Seven basic S.I. units, Derived units used in different scopes of physics : Electricity and magnetism, Mass and related quantities, Length and dimensional quantities, Time, Amount of substance, Temperature and thermal qualities, Photometry, Radioactivity, Radiometric sources and Fibre optics.

- **Fundamental unit of measurement** : It is a defined unit that cannot be described as a function of any other unit.
- The *International System of Units (SI)* defines seven fundamental units of measurement. They can be applied to the various areas of studying physical science.

SI base units :

- The International System of Units (SI) defined seven basic units of measurment from which all other SI units can be derived.
- These SI base units or commonly called metric units, are:

metre (m)	The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.
kilogram (kg)	The kilogram is the mass of the platinum-iridium prototype which was approved by the *Conference Generale des Poids et Mesures,* held in Paris in 1889, and kept by the Bureau International des Poids et Mesures at Paris in France.
second (s)	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.
ampere (A)	The ampere is the intensity of a constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.
kelvin (K)	The kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

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candela (cd)	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.
mole (mol)	The mole is the amount of the substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.

Derived units :

- There are numerous derived units that are complementary to the base units. They may have special names (e.g. hertz, pascal, becquerel, etc.) but can always be expressed in terms of the base units. However, there are also some dimensionless derived units.
- These units are linked together to form a consistent system and a coherent system.
- Lastly, each quantity may need to cover a vast range of values. To avoid the need for multiplying factors or values with a large number of zeros, prefixes are used. The prefixes cover a range extending from 10^{24} to 10^{-24} times the units.

Mass and Related Quantities	
The mass	**kilogram (kg)**
density : ρ	$kg.m^{-3}$
volume : V	m^3
force : F	newton (N) (Kg $m.s^{-2}$)
torque : τ	N.m
pressure : p	pascal (Pa) / Nm^{-2}
dynamic viscosity : η	Pa.s
kinematic viscosity : υ	$m^2.s^{-1}$
acoustic pressure : p	pascal (Pa)
dynamic volume : v	m^3
mass flow-rate : qm	$kg.s^{-1}$
volume flow-rate : qv	$m^3.s^{-1}$
air flow-rate : V	$m.s^{-1}$

Length and Dimensional Quantities	
wavelength : λ	metre (m)
length of material standards : L	metre (m)
plane angle : α	radian (rad)
form measurement :	metre (m)

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Electricity and Magnetism	
Current intensity	**The ampere (A)**
potential difference, V :	volt (V = W/A)
electrical capacitance, C :	farad (F = C/V)
electrical resistance, R :	ohm (Ω = V/A)
inductance, L :	henri (H = Wb/A)
electric conductance, G :	siemens (S = A/V)
quantity of electricity, Q :	coulomb (C = A.s)
power, P :	watt (W = J/s)
energy, W :	joule (J = N.m)
magnetic induction, B :	tesla (T = Wb/m^2)
electric field, E :	volt per metre (V/m)
magnetic field strength, H :	ampère per metre (A/m)
attenuation, η :	decibel (dB)

Radiometry – Photometry

Photometry	
➢ **Luminous intensity**	**candela (cd) (m)**
luminous flux : ϕ	lumen (lm)
illuminance : E	lux (lx)
luminance : L	cd.m^{-2}
➢ **Radiometry of sources**	
energy flow : ϕ_e	watt (W)
radiance : L_e	W.m^{-2}.sr^{-1}
irradiance : E_e	W.m^{-2}
laser source power : P	watt (W)
laser source energy : Q	joule (J)
➢ **Fibre optics :**	
energy flow : P	watt (W)
wavelength : λ	metre (m)
propagation time : t	second (s)
fibre length	metre (m)
linear attenuation factor :	dB.m^{-1}
reflectance	dB
detector (or fibre) pass band	hertz (Hz) (or Hz.m^{-1})

➢ **Temperature and thermal quantities :**

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➢ **Meterology of thermal quantities**		
thermal conductivity : $\lambda = \alpha.\rho.C_p$	(ρ = density)	$W.m^{-1}.K^{-1}$
thermal diffusivity : $\alpha = \lambda/\rho.C_p$	(ρ = density)	$m^2.s^{-1}$
specific heat capacity : $C_p = (\partial H/\partial T)_p$	(H = enthalpy)	$J.kg^{-1}.K^{-1}$
spectral directional emissivity : ε_λ	dimensionless ratio	
normal spectral emissivity : ε_λ	dimensionless ratio	
Total hemispherical emissivity : ε_λ	dimensionless ratio	

➢ **Hygrometry**		
temperature	dew point : T_d	degree Celsius (°C)
	frost point : T_f	degree Celsius (°C)
Relative humidity	with respect to water : U_w	percentage (%)
	with respect to ice : U_i	percentage (%)

Amount of Substance - Chemical Analysis

➢ The two main SI units used in the measurement of amount of substance contained in a material are the mole and the kilogram. From the definition of the mole (amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. There is a ratio between them; consequently, they are both used. More precisely, the measurement of an amount of substance is expressed either in mole or in kilogram, or as concentrations (ratio of two quantities: mass / mass, mole / mole, mole /mass, etc.).

Ionizing Radiation	
Radioactivity	
activity : A becquerel	Bq
activity per mass unit : A_m	$Bq.kg^{-1}$
activity per volume unit : A_v	$Bq.m^{-3}$
emission rate :	s^{-1}
emission rate per solid angle unit :	$s^{-1}.sr^{-1}$
neutron fluence rate :	$m^{-2}.s^{-1}$
Time And Frequency	
Time : the second	(s)
frequency : υ	hertz (Hz)
time interval :	second (s)
phase fluctuation spectral density :	(dB/Hz)
rotation speed	(tr/min)
Dimensionless Derived Units	
Plane angle	radian (rad) = $m \cdot m^{-1}$
Solid steradian angle	stéradian (sr) = $m^2 m^{-2}$

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Chapter 3 COMMONLY USED BASIC UNITS

Commonly used units in measurement of length, area, volume, pressure, temperature and mass of a substance.

Different Units Used In Measurement Of Length

SI unit of length : The base unit in the International System of Units (SI) also called MKS system is the metre, defined as "the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second. It is approximately equal to 1.0936 yards. Other units are derived from the metre by adding prefixes from the table below:

Standard prefixes for the SI units of measure

	Prefix name		deca	hecto	kilo	mega	giga	tera	peta	exa	zetta	yotta
	Prefix symbol		da	h	k	M	G	T	P	E	Z	Y
Multi-ples	Factor	10^0	10^1	10^2	10^3	10^6	10^9	10^{12}	10^{15}	10^{18}	10^{21}	10^{24}
	Prefix name		deci	centi	milli	micro	nano	pico	femto	atto	zepto	yocto
	Prefix symbol		d	c	m	μ	n	p	f	a	z	y
Fract-ions	Factor	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}	10^{-18}	10^{-21}	10^{-24}

Non-SI : In the Centimetre–Gram–Second (CGS) system of units, the basic unit of length is the centimetre, or 1/100 of a metre. Other non-SI units are derived from the decimal multiples of the metre.

Name	Symbol	SI value
fermi	fm	1 femtometre
angstrom	Å	100 picometres
micron	μm	1 micrometre
Norwegian/Swedish mil or myriametre		10,000 metres
x unit	xu	0.1 picometre

- The basic unit of length in the Imperial (U.K.) and (U.S.) customary systems is the yard, defined as exactly 0.9144 m by an international treaty in 1959.
- Common Imperial units and U.S. customary units of length include:
  thou or mil = 1/1000 of an inch
  line = 1/12 of an inch
  1 inch = 2.54 cm
  1foot = 12 inches, 0.3048 m
  1 yard = 3 ft, 0.9144 m
  1 (terrestrial) mile = 5280 ft, 1609.344 m
  1 nautical mile = 1852 m

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1 fathom(To measure the depth of an ocean) = 2 yards or 1.8288 m
1 (land) league = 3 miles

Marine length :

- fathom (for depth, only in non-metric countries) =2 yards
  Nautical mile (one minute of arc of latitude) = 1852 m
- Astronomy : Astronomical measure uses:
- Earth radius $R_{\oplus} \approx$ 6,371 km
- Lunar distance $LD \approx$ 384402 km, average distance between the center of the Earth and the centre of the Moon.
- Astronomical unit : AU, or defined as 149597870700 m. Approximately, it is the distance between the Earth and the Sun.
- Light-year (ly) : ≈ 9460730472580.8 km, the distance that light travels in a vacuum in one Julian year.
- Parsec (pc) : ≈ 30856775814671.9 km or about 3.26156 ly
- Hubble length : 14.4 billion light-years or 4.55 giga parsecs

Informal units of interest :

- Football field (generally around 110 metres, depending on the country)
- Thickness of a human hair (around 80 micrometres)
- A beard-second is a unit created as a teaching concept. It is the distance that a beard grows in a second (about 5 nanometres)
- Horse racing and other equestrian activities:
  furlong :≈ 0.125 miles (201 m)
  horse length :≈ 8 feet (2.4 m)

Different Units Used In Measurement Of Area

- There are many different units of area, such as 'square centimetres', 'hectares', 'square feet' and 'acres'.To change the units of a quantity, it is multiplied or divided by some constant value, called a conversion factor.

Unit name	Symbol	Metric equivalent	Imperial equivalent
Square centimetre	cm^2	$1cm^2$= 100 mm^2	$1cm^2$= 0.1550 in^2
Square metre	m^2	$1m^2$= 10,000 cm^2	$1m^2$= 1.1960 yd^2
Hectare	Ha	1ha= 10,000 m^2	1ha= 2.4711 acres
Squre kilometre	km^2	$1km^2$= 100 ha	$1km^2$= 0.3861$mile^2$
Square inch	In^2		$1in^2$ = 6.4516 cm^2
Square foot	ft^2	$1ft^2$= 144 in^2	$1ft^2$= 0.929 m^2
Square yard	yd^2	$1yd^2$ = $9ft^2$	1 yd^2 =0.8361 m^2
Acre	acre	1 acre= 4840 yd^2	1 acre = 4046.9 m^2
Square mile	$mile^2$	1 $mile^2$ =640 acres	$1mile^2$ = 2.59 km^2

Different Units Used In Measurement Of Volume

- In the International System of Units (SI), the standard unit of volume is the cubic metre (m^3). The metric system also includes the litre (L) as a unit of volume, where one litre is the volume of a 10-centimetre cube ($10cm^3$). Thus,

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1 litre = $(10\ cm)^3$ = 1000 cubic centimetres = 0.001 cubic metre
1 cubic metre = 1000 litres
1 millilitre = 0.001 litre = 1 cubic centimetre
1 centilitre = 0.01 litre
1 decilitre = 0.1 litre
1 kilolitre = 1000 litres
One teaspoon = 5 ml

- Various other traditional units of volume are also in use, including the cubic inch, the cubic foot, the cubic mile, the teaspoon, the tablespoon, the fluid ounce, the fluid dram, the gill, the pint, the quart, the gallon, the minim, the barrel, the cord, the peck, the bushel, and the hogshead.

Approximate conversion to millilitres:

Unit	Imperial	U.S. liquid	U.S. dry
Gill	142 mL	118 mL	138 mL
Pint	568 mL	473 mL	551 mL
Quart	1137 mL	946 mL	1101 mL
Gallon	4556 mL	3785 mL	4405 mL

Different Units Used In Measrement Of Temperature

- SI unit of measuring temperature is Kelvin but other units too are used for expressing temperature as listed below:

Conversion method:

K = °C + 273.15°
C = K – 273.15
$°C = (°F - 32) \times \frac{5}{9}$
$°F = \frac{9}{5}(°C + 32)$
1 °R (Rankine) = 1 °F = $^{5}D \times °C$ = $^{\circ}D \times K$
1 °Rø (Remer) = $^{40}D_{21}$ °C = $^{24}D_{7}$ °F
3.08 (12 °N(Newton) = 37 °C) and 3.03 (33 °N = 100 °C)

	Kelvin	Celsius	Fahrenheit	Rankine
Absolute zero (by definition)	0 K	–273.15°C	–459.67 °F	0 °R
Freezing point of brine	255.37 K	–17.78 °C	0 °F	459.67 °R
Freezing point of pure water	273.15 K	0 °C	32 °F	491.67 °R
Triple point of water (by definition)	273.16 K	0.01 °C	32.018 °F	491.688 °R
Boiling point of pure water (1 atm)	373.1339 K	99.9839 °C	211.97102 °F	671.64102 °R

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Common Temperature Reference Points			
	Celsius (°C)	**Kelvin (K)**	**Fahrenheit (°F)**
Surface of the Sun	5600	5900	10100
Boiling Point of Water	100	373	212
Body Temperature	37	310.2	98.6
Sweltering Day	40	313	104
Hot Day	30	303	86
Room Temperature	20	293	68
Cold Day	10	283	50
Freezing Point of Water	0	273	32

Different Units Used In Measurement Of Pressure

- The SI unit for pressure is the pascal (Pa), equal to one newton per square metre Nm^{-2} or $Kg.m^{-1}.s^{-2}$

Pressure units					
	pascal (Pa)	**bar (bar)**	**standard atmosphere (Atm)**	**torr (Torr)**	**pound per square inch (psi)**
1 Pa	a" 1 N/m^2	10^{-5}	9.8692×10^{-6}	7.5006×10^{-3}	145.04×10^{-6}
1 bar	10^5	a" 10^5 Pa	0.98692	750.06	14.5037744
1 at	0.980665×10^5	0.980665	0.96784	735.56	14.223
1 atm	1.01325×10^5	1.01325	a" p_o	760	14.696
1 Torr	133.322	1.3332×10^{-3}	1.3158×10^{-3}	H" 1 mm_{Hg}	19.337×10^{-3}
1 psi	6.895×10^3	68.948×10^{-3}	68.046×10^{-3}	51.715	a" 1 lbf/in^2

Different Units Used In Measurement of Time

- 1 second = A number of oscillations in a Cesium-133 or Iodine-127 atom.
- 1 minute = 60 seconds
- 1 hour = 60 minutes = 3,600 seconds
- 1 day = 24 hours = 1,440 minutes = 86,400 seconds
- 1 year = 365.25 days = 8,766 hours = 525,960 minutes = 31,557,600 seconds
- 1 leap year = 366.25 days (once every four years)
- 1 decade = 10 years
- 1 century = 10 decades = 100 years
- 1 millennium = 10 centuries = 100 decades = 1,000 years

Time in seconds

- decisecond = 1/10 second (10^{-1})
- centisecond = 1/100 second (10^{-2})
- millisecond = 1/1,000 second (10^{-3})
- microsecond = 1/1,000,000 second (10^{-6})
- nanosecond = 10^{-9} second
- picosecond = 10^{-12} second

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- femtosecond = 10^{-15} second
- attosecond = 10^{-18} second
- zeptosecond = 10^{-21} second
- yoctosecond = 10^{-24} second
- decasecond = 10 seconds
- shectosecond = 100 seconds
- kilosecond = 1,000 seconds (16.7 minutes)
- megasecond = 1,000,000 seconds (11.6 days)
- gigasecond = 10^9 seconds (31.7 years)
- terasecond = 10^{12} seconds (31,700 years)
- petasecond = 1^{15} seconds (31.7 million years)
- exasecond = 10^{18} seconds (31.7 billion years)
- zettasecond = 10^{21} seconds (31.7 trillion years)
- yottasecond = 10^{24} seconds (31.7quadrillion years)

Different Units Used In Measurement Of Mass

- The kilogram is the only standard unit to include an SI prefix (*kilo–*) as part of its name. The *gram* (10^{-3} kg) is an SI derived unit of mass. However, the *names* of all SI mass units are based on *gram*, rather than on *kilogram*, thus 10^3 kg is a *mega gram*.

Name	SI symbol	Value	Name	SI symbol	Value
decigram	dg	10^{-1} g	Decigram	dag	10^1 g
centigram	cg	10^{-2} g	hectogram	hg	10^2 g
milligram	mg	10^{-3}	kilogram	kg	10^3 g
microgram	mg	10^{-8}	megagram (tonne)	Mg	10^6 g
nanogram	ng	10^{-9} g	gigagram	Gg	10^9 g
pictogram	pg	10^{-3} g	teragram	Tg	10^3 g
femtogram	fg	10^{-15} g	petagram	Pg	10^{15} g
attogram	ag	10^{-18} g	exagram	Eg	10^{18} g
zeptogram	zg	10^{-21} g	zettagram	Zg	10^{21} g
yoctogram	yg	10^{-24} g	yottogram	Yg	10^{24} g

- 1 tonne (t) (or "metric ton") = 1000 kg.
- Atomic mass unit (u) = 1/12 of the mass of a carbon-12 atom (1.66×10^{-27} kg)

The atomic mass unit is convenient for expressing the masses of atoms and molecules

- 1 slug (sl) = 14.6 kg
- 1 pound (lb) is a unit of both mass and force = 0.45 kg or 4.5 N
- Planck mass (m_p) is the maximum mass of point particle.

$= 2.18\times10^{-8}$ kg

Units used in particle physics

- Solar ($M_\odot$) (mass of the Sun) $\approx 1.99 \times10^{30}$ kg.
- Compton wavelength (1 cm^{-1}) $\approx 3.52 \times 10^{-41}$ kg.
- Schwarzschild radius (1 cm) $\approx 6.73 \times 10^{24}$ kg.

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Chapter 4

Dimensional Formulae of Physical Quantities

Dimensional formula, computation of some common physical quantities, Greek symbols, some physical quantities without any dimensional formula, advantages and limitations in the writing of dimensional formula.

- **Dimensional formula :** It is the term that tells about the power with which a fundamental quantity is contained in a physical quantity.
- **Dimensional equation:** It is obtained when a physical quantity is equated with its dimensional formula.

  In general, $[X] = [M^a L^b T^c]$
- RHS represents dimensional formula of physical quantity X, whose dimensions in mass, length and time are a, b and c respectively.
- When velocity is defined using the fundamental units of mass, length and time, we have

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}} = LT^{-1} = M^0 LT^{-1}$$

  when there is no mass, $M^0 = 1$ (algebraic theory of indices).

  This is the dimensional formula for velocity and we can draw the following inference :
- Unit of velocity depends on the unit of length and time and is independent of mass.
- E.g., formula for density is ML^{-3}
- Formula for force is MLT^{-2}.

Dimensional Formulae Of Important Physical Quantities

- The dimensional formula of a physical quantity can be obtained by defining its relation with other physical quantities and then expressing these quantities in terms of mass [M], length [L] and time [T].
- **The dimensional formulae of some of the physical quantities are given below.**

Physical quantity	Relation with other quantities	Dimensional formula
Area	Length × breadth	$L \times L = L^2 = [M^0L^2T^0]$
Volume	Length × breadth × height	$L \times L \times L = L^3 = [M^0L^3T^0]$
Density	$\frac{\text{Mass}}{\text{Volume}}$	$\frac{M}{L^3} = [ML^{-3}\ T^0]$

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Physical quantity	Relation with other quantities	Dimensional formula
Speed or velocity	$\frac{\text{Distance}}{\text{Time}}$ or $\frac{\text{Displacement}}{\text{Time}}$	$\frac{L}{T} = [M^0LT^{-1}]$
Acceleration	$\frac{\text{Velocity}}{\text{Time}}$	$\frac{LT^{-1}}{T} = [M^0LT^{-2}]$
Momentum	Mass × velocity	$M \times LT^{-1} = [M\ LT^{-1}]$
Force	Mass × acceleration	$M \times LT^{-2} = [M\ LT^{-2}]$
Pressure	$\frac{\text{Force}}{\text{Area}}$	$\frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-1}]$
Work, Energy (K.E/ P.E. mechanical, heat, light, etc.)	Force × distance	$MLT^{-2} \times L = [ML^2T^{-2}]$
Power	$\frac{\text{Work}}{\text{Time}}$	$\frac{ML^2T^{-2}}{T} = ML^2T^{-3}$
Moment of force	Force × perpendicular	$MLT^{-2} \times L = ML^2T^{-2}$
Gravitational constant	$\frac{\text{Force} \times (\text{Distance})^2}{\text{Mass} \times \text{mass}}$	$\frac{MLT^{-2} \times L^2}{M \times M} = [M^{-1}L^3T^{-2}]$
Impulse	Force × Time	$MLT^{-2} \times T = [MLT^{-1}]$
Stress	$\frac{\text{Force}}{\text{Area}}$	$\frac{MLT^{-2}}{L^2} = [ML^{-1}\ T^{-2}]$
Strain	$\frac{\text{Change in dimension}}{\text{Original dimension}}$	Dimensionless
Coefficient of elasticity	$\frac{\text{Stress}}{\text{Strain}}$	$\frac{ML^{-1}T^{-2}}{\text{Dimensionless}} = ML^{-1}T^{-2}$
Surface tension	$\frac{\text{Force}}{\text{Length}}$	$\frac{MLT^{-2}}{L} = [ML^0\ T^{-2}]$
Surface energy	$\frac{\text{Energy}}{\text{Area}}$	$\frac{ML^{-1}T^{-2}}{L^2} [ML^0\ T^{-2}]$
Velocity gradient	$\frac{\text{Velocity}}{\text{Distance}}$	$\frac{LT^{-1}}{L} [M^0\ L^0\ T^{-1}]$
Coefficient of kinetic pressure	$\frac{\text{Force}}{\text{Area} \times \text{Velocity gradient}}$	$\frac{MLT^{-2}}{L^2 \times T^{-1}} = [ML^1\ T^{-1}]$

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Physical quantity	Relation with other quantities	Dimensional formula
Radius of gyration	distance	$[M^0L\ T^0]$
Moment of inertia	Mass × (radius of gyration)^2	$M \times L^2 = [ML^2T^0]$
Angle	$\frac{\text{Arc}}{\text{Radius}}$	Dimensionless
Angular velocity	$\frac{\text{Angle}}{\text{Time}}$	$\frac{\text{Dimensionless}}{T}$ $[M^\circ L^\circ\ T^{-1}]$
Angular momentum	$\frac{\text{Angular velocity}}{\text{Time}}$	$\frac{M^\circ L^\circ\ T^{-1}}{T} = [M^\circ L^\circ T^{-1}]$
Angular momentum	Moment of inertia × angular velocity	$\frac{ML^2}{M^\circ L^\circ T^{-1}} = [ML^2T^{-1}]$
Frequency	$\frac{1}{\text{Time period}}$	$\frac{1}{T} = [M^\circ L^\circ T^{-1}]$

Dimensional formulae of important physical constants :

Universal gravitational constant:

$$F = \frac{Gm_1m_2}{r^2} = [MLT^{-2}] = \frac{G.M.^2}{L^2} = [M^{-1}L^3T^{-2}] = Nm^2kg^{-2} = [M^{-1}\ L^3\ T^{-2}]$$

Planck's constant : $\frac{(ML^0T^{-2})}{T^{-1}}$ = J.s. = $[M^\circ L^2\ T^{-1}]$

Reynold's number $(N_R) = [M^0LT^{-1}]$

Hubble's constant : $\frac{(LT^{-1})}{L} = [M^0L^0\ T^{-1}]$

Boltzmann's constant : R/N, where N is Avogadro's number

$= (JK^{-1}) = [M^1L^2T^{-2}K^{-1}]$

Gas constant: $\frac{(ML^{-1}T^{-2})L^3}{k} = (JK^{-1}) = [M^{1-}L^2\ T^{-1}K]$

Wein's constant : $(mK) = [M^0L^1T^0K^1]$

Stefan's constant : $(Wm^{-2}K^{-4}) = [M^1L^0T^{-3}K^{-4}$

Faraday's constant: 1/mol x AT = (c) = $[M^0L^0T^1A^1mol^{-1}]$

- **Physical quantities with no units and dimensions:** Some of the physical quantities which are mostly the ratio have neither units nor any dimension. These are

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— Specific gravity	— Strain
— Avogadro's number	— Refractive index
— All trigonometric ratios	— Efficiency
— Dielectric constant	— Relative luminosity

Symbols and their usual meanings :

➢ The scientific group in Greece used the following symbols:

Theta - θ	Alpha - α	Beta - β
Gamma - γ	Delta - δ or Δ	Mu - μ
Lambda - λ	Omega - Ω / ω	Pi - π
Phi - ϕ	epsilone - $\in$	Psi - Ψ
Roh- ρ	Eta - η	Sigma - σ
Tau - τ	Kappa - κ	Chi - χ

Advantages and limitations in the writing of dimensional formulae:

➢ A dimensional formula is useful for the following applications.

1. To check the correctness of the given equation. This use is based on the principle of homogeneity, *i.e.* only quantities of, the same dimensions can be added, subtracted and equated. Hence, in a physical equation, every term should have the same dimensions.
2. To convert one system of units into another system of units, e.g., the numerical value of 10 joules in a new system of units in which the unit of mass is 10gm, unit of length 10cm and unit of time 10s can be determined using the concept that $n_1u_1 = n_2u_2$ where n_1, n_2 are the numerical values of a physical quantity and u_1,u_2 are the different units for the same physical quantity.
3. To derive the equations showing the relation between different physical quantities.

Limitations of dimensional system :

1. Dimensionless quantities cannot be determined by this method. Constant of proportionality cannot be determined by this method. They can be found either by experiment or by theory.
2. This method is not applicable to trigonometric, logarthmic and exponential functions.
3. In case of physical quantities which are dependent upon more than three physical quantities, this method is difficult.
4. In some cases, the constant of proportionality also possesses dimensions. In such cases, one cannot use this system.
5. If one side of equation contains addition or subtraction of physical quantities, one cannot use this method.

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PHYSICS

Chapter 5

MEASUREMENTS AND ERRORS IN PHYSICS

Measurements, use of standard units, fundamental and derived units, significant figure, value of zeros, order and scientific notations, accuracy, reliability and validity in measurements, systematic and random errors, ways to minimize the different types of errors and calculated errors.

- **Measurement :** All science is concerned with measurement to maintain uniformity across the world . Therefore, it's a fact that requires the known standards of measurement.
- **Standards :** In order to make meaningful measurements one needs the standards of commonly measured quantities, such as those of mass, length and time. These standards are as follows:
- The **kilogram** is the mass of a cylinder of platinum-iridium alloy kept at the International Bureau of Weights and Measures in Paris, France. By 2018, however, this standard may be redefined in terms of fundamental constants.
- The **metre** is defined as the length of the path travelled by light in a vacuum during a time interval of 1/299 792 458 of a second.
- The **second** is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.
- It is necessary for all such standards to be constant, accessible and easily reproducible.
- **SI Units :** The International System of Units, universally abbreviated SI (from the French *Le Système International d' Unités*), is the modern metric system of measurement. The SI was established in 1960 by the 11th General Conference on Weights and Measures (CGPM, *Conférence Générale des Poids et Mesures*). The CGPM is the international authority that ensures the wide dissemination of the SI and modifies the SI as necessary to reflect the latest advances in science and technology.
- Thus, the kilogram, metre and second are the SI units of mass, length and time respectively. They are abbreviated as kg, *m* and *s* respectively. Various prefixes are used to help express the size of quantities, e.g., a nanometre = 10^{-9} of a metre; a gigametre = 10^{9} metres.
- **Fundamental and Derived Quantities :** Physical quantities are not generally independent of one another. Many quantities can be expressed in terms of more fundamental quantities. The first three fundamental quantities, we will deal with, are those of mass, length and time. Many derived quantities, can be expressed in terms of these three fundamental quantities. For example, the derived quantity speed can be expressed as length/time.

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- **Dimensions :** The expression of a derived quantity in terms of fundamental quantities is called the dimension of the derived quantity. The symbol M is used to denote the dimension of mass, as is L for length and T for time. These dimensions can be used to check, the correctness of an equation. The dimensions of the left-hand side of the equation must equal the dimensions of the right-hand side. They can also be used to verify that different mathematical expressions for a given quantity are equivalent.
- **Significant figures :** Since the precision of all measuring instruments is limited, the number of digits that can be assumed as known for any measurement is also limited. When making a measurement, one needs to read the instrument to its smallest scale division. The figures one writes down for the measurement are called significant figures. For example, if one writes 3.0, it means that he is stating that he is able to estimate the first decimal place of the quantity and he is implying an error of 0.05 unit. If one writes 3, he is unable to determine the first decimal place, hence, implying an error of 0.5 unit.
- A calculated quantity cannot have more significant figures than the measurements or supplied data used in the calculation e.g., if the length, breadth & height of a rectangular prism is each known to 2 significant figures, the volume calculated from these figures cannot have more than 2 significant figures. Let's say the volume = 3.7cm × 2.9cm × 5.1cm = 54.723 cm^3, *i.e.* the volume is 55cm^3 (2 significant figures only).
- **Zeros**
- Zeros between the decimal point and the first non-zero digit are not significant, e.g., 0.00035 has 2 significant figures.
- Zeros that round off a large number are not significant, e.g., 35,000 has 2 significant figures.
- Zeros at the end of a string of decimals are significant. e.g. 0.5500 has 4 significant figures. The last 2 digits are meaningful here. The measurement is 0.5500, not 0.5501 or 0.5499.
- Zeros in between non-zero digits are significant, e.g., 0.7001 has 4 significant figures. The first zero is not significant but the next two are.
- **Order and Scientific notation :** The order of a number is the nearest power of 10 to that number, e.g., 166,000 has an order of 10^5; 756,000 has an order of 10^6; 0.099 has an order of 10^{-1}.
- In Physics, quite often scientific notation is used. Write one non-zero figure before the decimal point and correct the magnitude of the number by using the appropriate power of ten, e.g., 166,000 can be written as 1.66 x 10^5; 0.099 can be written as 9.9 × 10^{-2}.
- **Accuracy, reliability and validity :** These three terms are often used when referring to experiments, experimental results and data sources in science. Hence, it is important to have a good understanding of the meaning and use of these terms.

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- **Accuracy (Conformity to truth) :** Scientific texts refer to accuracy in two ways:
- **Accuracy** of a result or experimental procedure can refer to the percentage difference between the experimental result and the accepted value.
- **Accuracy** is also associated with the inherent uncertainty in a measurement.
- **Reliability (Trustworthy or dependable) :** In terms of first-hand investigations reliability can be defined as repeatability or consistency. If an experiment is repeated many times and give identical results each time it is reliable. In terms of second- hand sources, reliability refers to how trustworthy the source is.
- **Validity : (Derived correctly from premises already accepted, eliminated or supported by actual fact)** A valid experiment is one that fairly tests the hypothesis. In a valid experiment, all variables are kept constant apart from those being investigated, all systematic errors have been eliminated and random errors are reduced by taking the mean of multiple measurements. An experiment could produce reliable results but it will be invalid if it gives inaccurate and invalid results because a valid scientific experiment would produce reliable results in multiple trials.
- **Nature of errors :** Errors occur in all physical measurements. When a measurement is used in a calculation, the error in the measurement is carried forward in the result. The two different types of **errors** that can occur in a measured value are:
- **Systematic error :** It occurs to the same extent in each one of a series of measurements, e.g., zero error, where for instance the needle of a voltmeter is not correctly adjusted to read zero, when no voltage is present.
- **Random error :** It occurs in any measurement as a result of variations in the measurement technique (e.g. parallax error, limit of reading, etc).
- **Errors in measured quantity :** The error can be
- **Absolute error :** It is the actual size of the error expressed in the appropriate units
- **Relative error :** It is the absolute error expressed as a fraction of the actual measured quantity.

Improving reliability, accuracy and validity : To reduce the relative error, one must

- use appropriate measuring instruments in the correct manner (e.g. using of a micrometer or screw gauge rather than a metre ruler to measure the diameter of a small ballbearing)
- take the mean of multiple measurements. To improve the accuracy and validity of an experiment one needs to keep all variables constant other than those being investigated
- eliminate all systematic errors by careful planning and performance of the activity requiring measurement
- reduce random errors as much as possible by taking the mean of multiple measurements.

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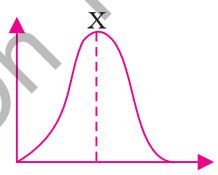
Experimental errors : Variations occur in any series of measurements taken with a suitably sensitive measuring instrument. These variations in the different readings of a measurement are called "experimental errors". These variations are normal.

Random errors : These variations are caused by slight variations in the measuring technique such as :

- closing the jaws of the micrometer more or less tightly from one measurement to the next such as obtaining a set of readings in mm such as: 0.73, 0.71, 0.75, 0.71, 0.70, 0.72, 0.74, 0.73, 0.71 and 0.73 while using a micrometer to find the diameter of a wire.
- Similarly, an angle other than perpendicular to the scale that introduces parallax error into the results.
- Such factors cause random variations in the measurements and hence, called Random Errors.
- These errors are avoided or minimized by plotting a distribution curve by making readings or measured values of a quantity lie along the x-axis and the frequencies (number of occurrences) of the measured values along the y-axis.
- The Normal Curve is a smooth, continuous curve and symmetrical about a central "x" value. The peak in frequency occurs at this central x value.
- The effect of random errors on a measurement of a quantity can be largely nullified by taking a large number of readings and finding their mean value. The formula for the mean is as shown below :

$$\bar{X} = \Sigma X$$



- X is mean, Σx is the sum of readings and n is the total number of readings.
- **Effects of random errors:** To take into account the effects of random errors in analysing and reporting the experimental results, one should
  - Take a large number of readings – at least 10, where time and practicality permit.
  - Calculate the mean of the readings as a reasonable estimate of the "true" value of the quantity.
  - Use the largest deviation of any of the readings from the mean as the maximum probable error in the mean value.
  - If all the readings are the same, use half the limit of reading of the measuring instrument as the MPE(Mean Percentage Error) in the result.

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- **Systematic errors** : These errors occur to the same extent in each one of a series of measurements. Causes of systematic error include :
  - Using the instrument wrongly on a consistent basis.
  - Built-in error in the instrument may be zero error. In case, the instrument has not been correctly set to zero before commencing the measuring procedure.

    External conditions can introduce systematic errors such as a metallic rule calibrated for use at 25°C will only be accurate at that temperature. If one uses this rule at 5°C, it will produce readings that are consistently larger than they should be since at the lower temperature the metal will have contracted and the distance between each scale division would be smaller than it should be.
- Systematic errors can drastically affect the accuracy of a set of measurements. In order to reduce the incidence of these errors, the experimenter must:
  - Use all measuring instruments correctly and under the appropriate conditions.
  - Check for zero error.
- **Errors in Calculated Quantities :** In scientific experiments the measured values are used of particular quantities for calculating a new quantity. The error in the new quantity depends on the errors in the measured values used for calculating it because of an error in
  - addition or subtraction
  - multiplication or division
  - changing of unit values from MKS to CGS or vice versa.

Problem : A student while heating water measured the starting temperature to be (35.0 ± 0.5)°C and the final temperature to be (85 ± 0.5)°C. Find the change in temperature.

Solution : The change in temperature is

(85.0 – 35.0)°C ± (0.5+0.5)°C or (50.0 ± 1.0)°C

Problem : Find the volume of a ball bearing in cm^3 of radius 9.53 mm ± 0.05 mm.

Ans. The formula for the volume of a sphere is : $V = 4/3\pi r^3$

Using this formula, the value for the volume of the ball bearing is found to be 3625.50mm^3.

Percentage of error in volume = % error in r + % error in r + % error in r. Therefore, % error in volume = 0.5% + 0.5% + 0.5% = 1.5%

The volume of the ball bearing is, therefore, 3625.50 mm^3 ± 1.5% or 3625.50mm^3 ± 54.38mm^3.

Changing mm^3 to cm^3, the volume of the ball bearing is (3.63 ± 0.05)cm^3.

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Chapter 6

KINEMATICS

Kinematics, scalar and vector quantities with examples, Dimensional motion: one, two and three dimensional motions, types of motion, distance (s), displacement, average velocity v / s instantaneous velocity, acceleration, four kinematic equations and projectile motion with equations related to motion in trajectory.

- **Kinematics :** It refers to the study and description of motion, without regard to its mass or physical quantities that depend on mass. One of the basic difference between kinematics and dynamics is that dynamics is the cause of motion and kinematics is the effect.
- Kinematics involves position, velocity and acceleration (and their rotational equivalents)
  - Position is the point in space that an object occupies. It needs to be defined in a coordinate system.
  - Velocity is the rate of the change of position with respect to time.
  - Acceleration is the rate of change of velocity with respect to time.

Scalar and vector quantities	A scalar quantity is a one-dimensional measurement of a quantity, like temperature or weight. A vector has more than one number associated with it. A simple example is velocity. It has a magnitude, as well as a direction, like South or 10 degrees west of North.
Examples of scalar quantities	Mass, distance, time , speed, volume, density, pressure , work, energy, power, charge ,electric current, electric potential, electric conductance, electrical and magnetic flux, inductance, resistance, specific heat, frequency, moment of inertia, radioactivity, Young's modulus, etc.
Examples of vector quantities	Displacement, velocity, acceleration, force, weight, momentum, impulse, electric field, magnetic field, current density, etc.

- **Dimensional motion of a body :** A body is said to be in motion if its position changes with respect to its surrounding. In order to completely describe the motion of such objects, we need to specify its position. For this, we need to know the position coordinates. In some cases, three position coordinates are required, in some cases, one or two coordinates are required. Based on these, motion can be classified as one, two or three dimensional motion.
- **Motion in one dimension :** It is also called rectilinear or linear motion in which a particle moves along a straight line such that only one of the three coordinates changes with time so as the motion

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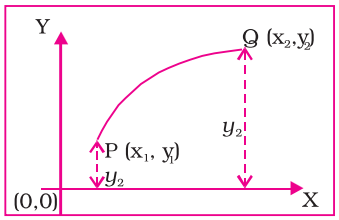
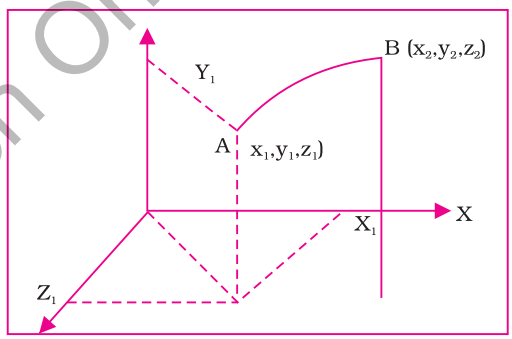
of a train along a straight line, upward and downward oscillation of a vertical spring or freely vertically falling of a body under the force of gravity.

- **Motion in two dimensions:** A particle moving along a curved path in a plane shows the two dimensional motion. The figure illustrates a two dimensional motion where a particle moves from $P(x_1,y_1)$ to $Q(x_2,y_2)$ along a curved path. The other examples include :



  - a satellite revolving round the earth.
  - an insect crawling on a ball.
  - motion of a particle thrown obliquely into the air like a golf ball after being hit by a golf stick.
  - oscillation of a bob of a simple pendulum in a vertical plane with a large amplitude. In case of a small amplitude the oscillation is almost in a straight line. and the motion is one dimensional.
- **Motion in three dimensions:** A particle moving in space has three dimensional motion. In this type of motion , all the coordinates change with time.
- The figure illustrates this type of motion where the particle moves from A to B and the corresponding rectangular coordinates change from (x_1,y_1,z_1) to (x_2,y_2,z_2) . This type of motion is well exhibited by



  - a bird or kite flying in the air
  - a fish swimming in water.
- **Types of motion :** Motion may be divided into three basic types — translational, rotational and oscillatory.
- **Translational motion :** It results in a change of location, *i.e.* walking a distance of 400m from point A to point B or a football being kicked by a player to his fellow team mate.

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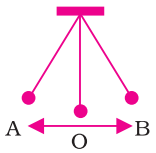
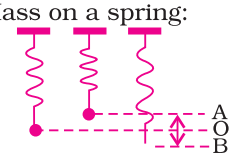
- **Oscillatory motion :** It is repetitive and fluctuates between two fixed locations such as for a person going from home to work to home to work. In the end, it means that the person has not gone anywhere. This type of motion is seen in pendulums , vibrating strings, drawers and doors with hinge joints.

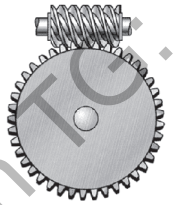
Simple pendulum



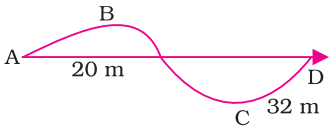
Mass on a spring:



- Oscillatory motion is interesting because it often takes a fixed amount of time for an oscillation to complete. This kind of motion is said to be periodic and the time for one complete oscillation (or one cycle) is called time period.
- **Rotational motion :** It mostly occurs when an object spins about an axis like the earth, hands of a clock or motion of a moving car or bicycle wheel. In this motion, a particle returns to its initial position like oscillatory motion after a particular time to eventually have zero displacement.



- **Random motion :** It refers to the free undirected, uncertain and unpredictable motion such as the motion of the molecules of a fluid in a container.
- **Distance v/s Displacement :** Distance is the total length travelled along a path. It's a scalar quantity. The displacement is vector connecting a point to the origin or from one point to another point later in time (in SI, abbreviation for displacement is s). It can be considered as the shortest distance from the point of origin.



- ABCD the total path travelled =32 m is the distance while AD = 20m, the shortest distance from the point of origin of motion is the displacement.
- Distance travelled is always positive, displacement can be positive, zero or negative.

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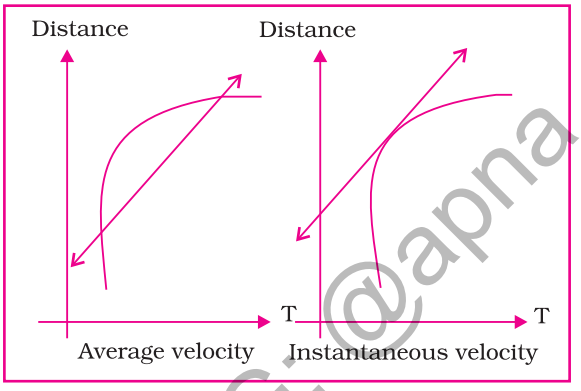
- Distance is a scalar quantity but displacement is a vector quantity.
- **Instantaneous velocity v/s Average velocity :** The speed of a body in motion is the rate of change of distance but velocity is the rate of change of displacement.
- The direction of velocity vector is same as the direction of motion. The average velocity is the change in displacement over a finite duration, (Δ t).
- Graphically, it represents the slope of secant, shown in the figure. The instantaneous velocity (v) is slope (tangent) to the displacement-time curve at a particular instant (t).



- **Acceleration :** It is a vector quantity that is defined as the rate at which an object changes its velocity. An object is considered to be accelerating if it is changing its velocity. If an object undergoes a change in its velocity, then only the object is said to be accelerating, otherwise not. (acceleration = change in velocity/time).
- When an accelerating object changes its velocity by the same amount, each second, the acceleration is referred to as a constant acceleration since the velocity is changing by a constant amount each second. An object with a constant acceleration should not be confused with an object with a constant velocity. If an object changes its velocity -whether by a constant amount or a varying amount - then it is an accelerating object but an object with a constant velocity may not be accelerating.
- The average acceleration (a) of any object over a given interval of time (t) is calculated using the equation in the S.I. units of m/s^2 or ms^{-2}.

  $$\text{Average acceleration} = \frac{\text{Velocity}}{\text{Time}} = \frac{V_2 - V_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

- When an object speeds up with the acceleration in the same direction as the velocity, the object has a positive acceleration. When the object moves in the *positive* direction (*i.e.* has a positive velocity) but slowing down then the acceleration is in the opposite direction as the velocity. The object will be considered to have negative acceleration.

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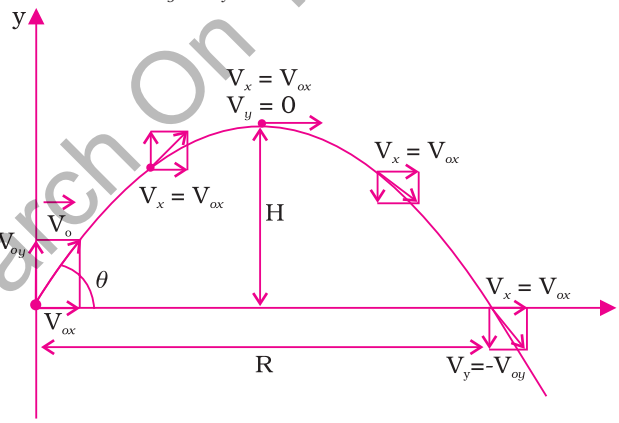
- **Retardation :** If refers to the negative acceleration such as a decline in velocity of a body in motion after applying brakes.
- **Kinematic equations :** The kinematic equations are a set of four equations that can be utilized to predict unknown information about the motion of an object if other information is known. The four kinematic equations that describe the motion of an object are:
  - $v_f = v_i + at$ or $v = u + at$
  - $d = v_I t + ½ at^2$ or $s = ut + ½ at^2$
  - $v_f^2 = v_i^2 + 2ad$ or $v^2 = u^2 + 2as$
  - $d = \frac{V_i + V_f}{2} \times t$ or $s = \frac{\Delta V}{2} \times t$
- There are a variety of symbols used in the above equations. Each symbol has its own specific meaning. The symbol 'd' stands for the displacement of the object. The symbol 't' stands for the time for which the object moved. The symbol 'a' stands for the acceleration of the object. And the symbol 'v' stands for the velocity of the object; A subscript of i after the v (as in v_i) indicates that the velocity value is the initial velocity value(u) and a subscript of f (as in v_f) indicates that the velocity value is the final velocity value(v).
- **Projectile motion :** A projectile is an object thrown upward into the air or space. The curved path along which the projectile travels is what is known as trajectory. Projectile Motion is the free fall motion of any body in a horizontal path with constant velocity.

  Horizontal distance, $x = V_x t$
  Horizontal Velocity, $V_x = V_{xo}$
  Vertical distance, $V_y = V_{yo} t - gt^2$
  Vertical Velocity, $V_y = V_{yo} - gt$



Where,
V_x is the velocity along x-axis,
V_{xo} is the initial velocity along x-axis,
V_y is the velocity along y-axis,
V_{yo} is the initial velocity along y-axis.
g is the acceleration due to gravity and
t is the time taken

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- Equations related to trajectory motion (projectile motion) are given by,

Time of flight , $t = \frac{2v_o \sin\theta}{G}$

Maximum height, $H = \frac{v_o^2 \sin^2\theta}{2g}$

Horizontal range, $R = \frac{v_o^2 .2\sin\theta}{g}$

Where,

V_o is the initial Velocity,

sin θ is the component along y-axis,

- Projectile Motion formula is used for finding the distance, velocity and time taken in the projectile motion.

Problem : Ramesh in his car can accelerate from zero to 60 mph (26.8 m/s) in 4.9 s.

(i) What is the average acceleration of the car during that period of time?

(ii) If acceleration of the car is constant, how far does the car travel in those 4.9 s?

Solution : (i) $v_i = 0$ $v_f = 26.8$ m/s

$t_1 = 0$ $t_2 = 4.9$ s

$x_1 = 0$ $x_2 = ?$

$v_f = v_i + a\Delta t$

26.8 m/s = 0 + a (4.9 s)

26.8 m/s /4.9 s = a

$5.5 m/s^2 = a$

(ii) $x_2 = v_i t + ½ at^2$

$x_2 = 0 \times t + ½ \times 5.5 m/s^2 \times (4.9 s)^2$

$x_2 = 0 + 66$ m

$x_2 = 66$ m

Problem : A javelin travels in a parabolic arc for 6 seconds before hitting the ground. Compare its horizontal velocity 1 second after being thrown to its horizontal velocity 4 seconds after being thrown.

Solution : Assuming that the air resistance is negligible, there is no acceleration in the horizontal direction during a projectile motion. Therefore, the horizontal velocity of the javelin will not change at any time during the flight. So, its horizontal velocities 1 second and 4 seconds after being thrown will be the same.

Problem : One second after a rock being thrown straight down from the top of a tower falls at 20 m/s. How fast will it fall 2 seconds later?

Solution : Since the initial velocity is in the downward direction, it will have a negative value.

With $v_i = -20$ m/s , $a = -9.8 m/s^2$, $\Delta t = 2$ s, $v_f = ?$

$v_f = {}_v i + at$

$= -9.8 \times 2 - 20$ m/s

$= -19.6 - 20 m/s = -39.6 m/s$

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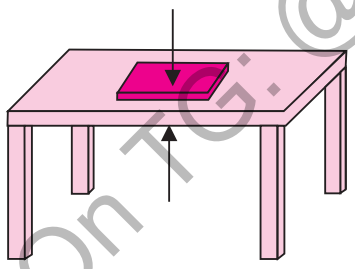
Chapter 7

NEWTON'S LAW OF MOTION

Newton's first law of motion, external and internal force, net force, balanced and unbalanced force, inertia and its types with examples, Newton's second law of motion and its applications , momentum, law of conservation of momentum, impulse, Newton's third law of motion and its applications.

- **Matter :** At one time, matter was known to be anything that occupies space and has mass but with upcoming of the understanding of Newton's laws of motion developed a new fact about matter defining it to be anything that occupies space and has its own mass and inertia.
- Inertia of a body describes its physical state, *i.e.* state of rest or motion.
- **Newton's first law :** An object at rest remains at rest, or if in motion, remains in motion at a constant velocity, *i.e.* tends to retain its inertia until and unless acted on by a net external force. Hence, Newton's first law of motion also came to be considered as the law of inertia.



- Force, external force and net force : Force is a push or a pull exerted on one object by another object. The units of force 'F' are called Newtons or simply N.
- The external force is the force acting from outside on an object rather than the force from inside of an object. For instance, the force of gravity that the Earth exerts on the moon is the external force on the moon. However, the force of gravity that the inner core of the moon exerts on the outer crust of the moon is an example of internal force on the moon. Internal forces within an object can't cause a change in the overall motion of that object.
- The net force, written as ΣF, on an object is the sum total forces that acts on an object. If many forces act on an object then the net force is the sum of all the forces. Force F is a vector, to find the net force ΣF, the forces must be added up like vectors using vector addition.
- In other words, if a box lying on a table had a force of magnitude 25 N exerted on it to the right and a force of magnitude 15 N exerted on it to the left, the net force in the horizontal direction would be

$$\Sigma F_{\text{horizontal}} = 25\text{N} - 15\text{N} = 10\text{N}$$

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- **Balanced and unbalanced force :** The concept of the net force that acts on a body has brought up the concept of balanced and unbalanced force. A force that fails to bring any change in the inertia of a body is called the balanced force while a force which being greater than the sum of all the forces acting on a body, brings a change in the inertia of a body is called the unbalanced force.
- Newton's first law implies that if the net force on an object is zero (ΣF=0) then that object will have zero acceleration. However, it doesn't necessarily mean the object is at rest, but it means that the velocity is constant. In other words, constant zero velocity - at rest - or constant non-zero velocity - moving with a constant velocity such as a bird gliding in air at a particular height and velocity has zero acceleration.
- **Three types of inertia :** Inertia is that property of a body by virtue of which the body is unable to change its state by itself in the absence of external force. The inertia is of three types :
- **Inertia of rest :** It's ability of the body to resist any change in its state of rest such as
  - A person standing in a bus falls backward when the bus suddenly starts moving because the person initially at rest continues to be at rest even after the bus has started moving .
  - A book on the table or a rock on ground remains at rest, until it is moved by some external agency applying the unbalanced force to displace it.
  - When a carpet is beaten with a stick, the dust particles fall off vertically downward once they are released and do not move along the carpet before falling off.
- **Inertia of motion :** It refers to the inability of the body to change its state of motion by itself such as
  - when a passenger gets down from a moving bus, he tends to fall down in the direction of the motion of the bus.
  - a passenger sitting in a moving car falls forward, when the car stops suddenly. The belt used by the car driver is meant to prevent the same when the driver has to apply sudden brakes.
  - an athlete running a race continues to run for some distance even after reaching the finishing line.
  - ripe fruits fall from a tree in the direction of wind. As the tree sways along with the wind and the inertia of motion makes these fruits sway along with the tree branches. The fruits fall off due to the inertia of motion along the direction of wind.
  - the swirling of milk in a glass continues even after the stirring is stopped due to the inertia of motion of the milk inside the glass.
- **Inertia of direction :** It is the inability of the body to change its direction of motion by itself such as
  - tangentially straight motion of a rock moving in circular path after being released.

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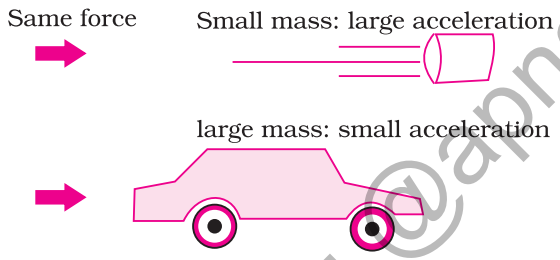
- curving of the steering wheel by a car driver when going round on a circular path.
- sideways falling of a passenger sitting in bus when the bus takes a sharp turn or goes round on a circular path.
- protection by an umbrella on a rainy day. The rain drops falling vertically downwards cannot change their direction of motion and so fail to wet us when the umbrella is up.

➢ **Newton's second law of motion:** Newton's first law states that a body tries to retain its inertia unless an unbalanced force is applied on it. But what happens if the unbalanced force is applied; it is described by Newton's Second Law of Motion. It states, "The force acting on an object is equal to the mass of that object times its acceleration."



Force = mass × acceleration

➢ This is written in mathematical form as : $F = ma$

➢ F is force, m is mass and a is acceleration. The relation clearly describes that if one
- increases the force by two times, the acceleration possessed by the body also increases by two times.
- increases the mass by two times, the acceleration is reduced to half of its initial value with $a = F/m$.

➢ The force applied on an object at rest causes it to accelerate in the direction of the force. However, if the object is already in motion, or if this situation is viewed from a moving inertial reference frame, the body might appear to speed up, slow down or change its direction depending on the direction of the force and the directions that the object and reference frame are moving relative to each other.

➢ In the relation $F = ma$ both force and acceleration are vector quantities, *i.e.* they have both magnitude and direction. The force can be a single force or it can be the combination of more than one force. Hence, the equation is to be written as : $\Sigma F = ma$.

➢ The large Σ represents the vector sum of all the forces, or the net force acting on a body.
- Some elevator has a sign saying that only a certain amount of people can use it at a time because it has a maximum acceleration and force with which it move, *i.e.* it can sustain only a maximum mass, which is then translated into a certain number of people.

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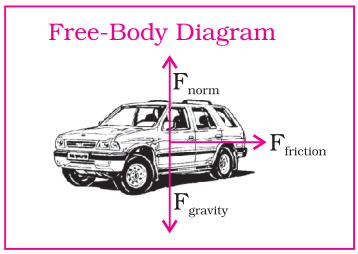


❖ Consider a car moving in a horizontal circle on a level surface. Applying the concept of a centripetal force requirement, the net force acting upon the object is directed inwards. Since the car is positioned on the left side of the circle, the net force has to be directed rightwards.

Problem : A 10 kg object is forced to the left with 10 Newton and to the right with 20 Newton force. What is the acceleration of this object?

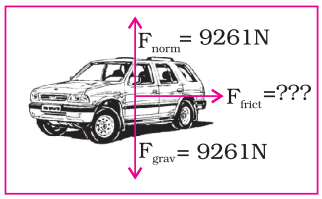
Solution : Mass of object = 10 kg
Force to the left = 10N
Force to the right = 20N
Net force = $F_{Right} - F_{left}$
= 20N –10N = 10N
With $\sum F = m \times a$
$a = \sum F/m$ = 10 N/10 kg = $1 ms^{-2}$

Problem : The maximum speed with which a 945 kg car makes a 180-degree turn is 10.0 m/s. The radius of the circle through which the car turns is 25.0 m. Find the force of friction and the coefficient of friction acting upon the car.

Solution :

Known information	Requested information
M = 945 kg	F_{fric} = ?
V = 10.0 m/s	μ (Coefficient of friction) = ?
r = 25 m	

➢ With no vertical acceleration of the car, the vertical forces balance each other. Thus,



F_{grav} = m g when g is 9.8 m/s^2.
$F_{grav} = F_{norm}$ = 945 x 9.8 = 9261 N.

➢ Hence two of the three forces identified in the free-body are as shown in the diagram. Only the horizontal frictional force remains unknown.

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- To determine the net force, the mass and the kinematic information (speed and radius) must be substituted in the equation:

$$F_{net} = m \times v^2/r$$
$$= 945 \times (10)^2/25 = 3780 \text{ N}$$

- Finally the coefficient of friction can be determined using the equation that relates the coefficient of friction to the force of friction and the normal force.

$$F_{fric} = \mu \times F_{norm}$$
$$\mu = F_{Fric} / F_{norm}$$
$$= 3780/9261 = 0.408$$

- Therefore, the coefficient of friction is 0.408.
- Momentum : The momentum of a particle represented by letter p is the product of two quantities: the mass (represented by the letter m) and velocity (v), *i.e.* $p = m.v$
- The units of momentum are the product of the units of mass and velocity. In SI units, if the mass is in kilograms and the velocity in metres per second then the momentum is in kilogram metres/ second (kg m/s). In CGS units it is (g cm/s).
- Being a vector, momentum has magnitude and direction. For example, a 1 kg model airplane, traveling due north at 1 m/s in straight and level flight, has a momentum of 1 kg m/s due north measured from the ground.
- **Many particles :** The momentum of a system of particles is the sum of their momenta. If two particles have masses m_1 and m_2, and velocities v_1 and v_2, the total momentum is

$$P = p_1 + p_2$$
$$= m_1v_1 + m_2v_2$$

- The momenta of more than two particles can be added more generally with the following :

$$p = \Sigma m_1 v_1$$

- A system of particles has a centre of mass, a point determined by the weighted sum of their positions :

$$r_{cm} = \frac{m_1r_1\ m_2r_2 + \ldots\ldots\ldots\ldots}{m_1 + m_2 + \ldots\ldots\ldots\ldots\ldots\ldots} = \frac{\sum_i m_1\ r_1}{\sum_i m_1}$$

- If all the particles are moving, the centre of mass will generally be moving as well (unless the system is in pure rotation around it). If the centre of mass is moving at velocity v_{cen}, the momentum is : $P = m.\ v_{cen}$
- This is known as Euler's first law.
- **Relation to force :** If a force F is applied to a particle for a time interval Δt, the momentum of the particle changes by an amount

$$\Delta p = F \Delta t$$

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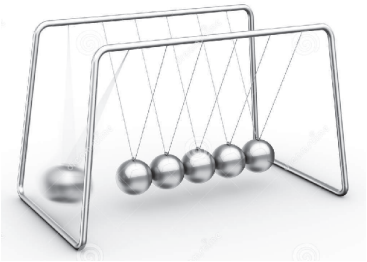
- **Conservation of momentum :** A system of particles has a centre of mass, a point determined by the weighted sum of their positions.



Newton's cradle

- In a closed system (one that does not exchange any matter with its surroundings and is not acted on by external forces), the total momentum is constant. This fact, known as the law of conservation of momentum, is implied by Newton's laws of motion. Suppose, for example, when two particles interact because of the third law, the forces between them are equal and opposite. If the particles are numbered 1 and 2, the second law states that $F_1 = dp_1/dt$ and $F_2 = dp_2/dt$.

  Therefore, $(dp_1/dt) = -(dp_2/dt)$ with the negative sign indicating that the forces oppose. Equivalently, $dt(p_1 + p_2) = 0$
- If the velocities of the particles are u_1 and u_2 before the interaction, and afterwards, they are v_1 and v_2, then

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

- This law remains valid no matter how complicated the force is between particles. Similarly, if there are several particles, the momentum exchanged between each pair of particles adds up to zero, so the total change in momentum is zero. This conservation law applies to all interactions, including collisions and separations caused by explosive forces.
- **Law of conservation of momentum :** Conservation of momentum is derived from Newton's laws of motion. Newton's third law states that every action has an equal but opposite reaction *i.e.* the force that one object A exerts on object B is equal but opposite to the force that object B exerts on object A. By Newton's second law, this force is equal to the product of the mass and the acceleration of the objects, so the product of the mass and acceleration of object A is equal but opposite to the product of the mass and acceleration of object B.
- Hence, the law of conservation of momentum states that for two objects colliding in an isolated system, the total momentum before and after the collision is equal. This is because the momentum lost by one object is equal to the momentum gained by the other.

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Problem : Determine the momentum of
(a) 1000 kg car moving northward at 20 m/s.
(b) 40 kg freshman moving southward at 2 m/s.

Solution : (a) p = m x v = 1000 kg x 20 m/s
p = 20,000 kg.m/s, north
(b) p = m x v = 40 kg x 2 m/s
p = 80 kg.m/s

Problem : A mass of 4 kg is moving at a speed of 10 m/s in a frictionless surface. It collides with a 3kg mass moving in the same direction at 5 m/s. What is the final velocity of the system after the collision?

Solution : Using the conservation of momentum,
we see that

$m_1v_1 + m_2v_2 = (m_1+m_2)v_f$

$4 \times 10 + 3 \times 5 = 7kg\ v_f$

$55kgm/s = 7kg\ v_f$

$v_f = 7.857$ m/s

Problem : There are two vehicles moving at a speed of 50 km/s and 70 km/s with mass of 100 kg and 60 kg respectively. Find the final speed of both after collision.

Solution : We've

$m_1v_1+m_2v_2 = (m_1+m_2)v_f$

$100 \times 50 + 60 \times 70 = (100 + 60)v_f$

$v_f = 9200 / 160 = 57.5$ km/s

- **Impulse :** It (symbolized as J or Imp) is the integral of a force, F, over the time interval, t, for which it acts.

$$J = F.\Delta t$$

- Since force is a vector quantity, impulse is also a vector in the same direction. Impulse applied to an object produces an equivalent vector change in its linear momentum in the same direction. Impulse has the same units and dimensions (MLT^{-1}) as momentum. In the (SI) International System of Units, these are kg·m/s or N/s.
- **Newton's third law of motion :** Whenever two bodies interact with each other, the force exerted by the first body on the second is called action. The force exerted by the second body on the first body is called reaction. Newton's Third Law of Motion states that in each interaction to every action, there is an equal and opposite reaction. The action and reaction always act on different objects. The Third Law of Motion indicates that when one object exerts force on another object, the second object instantaneously exerts force back on the first object. These two forces are always equal in magnitude, but opposite in direction.

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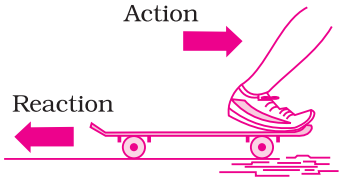
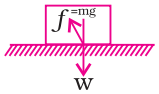
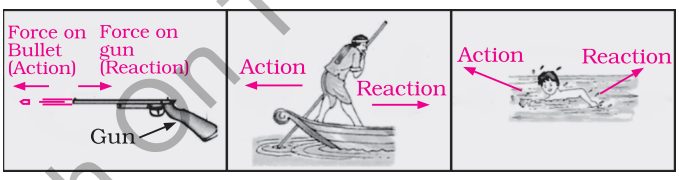


- These action and reaction forces act on different objects and so they do not cancel each other. Thus, Newton's Third Law of Motion describes the relationship between the forces of interaction between two objects.
- For example, when we place a wooden block on the ground, the block exerts force equal to its weight, W = mg acting downwards to the ground. This is the action force. The ground exerts an equal but opposite force W = mg on the block in the upward direction. This is the reaction force.



- **A gun recoils when a bullet is fired from it :** When a bullet is fired from a gun, the gun exerts force on the bullet in the forward direction. This is the action force. The bullet also exerts an equal force on the gun but in the backward direction. This is the reaction force. Due to the large mass of the gun, it moves only a little distance backward by giving a jerk at the shoulder of the gunman or soldier. The backward movement of the gun is called the recoil of the gun.



- Similarly, a sailor rowing a boat, a swimmer swimming in water, a person walking or running on ground or the propulsion of a rocket in the air on its way to a space station are the examples of the applications of Newton's third law of motion.
- In a car crash, the action forces are the cars colliding with each other. The reaction force is the force sent back due to the collision, the one that causes the damage to the car. When two cars are headed straight at each other, they are travelling in opposite directions. When they finally collide, if they apply the same amount of force, they will experience a reaction of equal magnitude. This causes the destruction of the front of both cars. Since force is the product of mass and acceleration. If a heavier car, *i.e.* car with more mass collides with car having comparatively less mass, there if the two are travelling at same acceleration, the heavier car is going to experience less damage compared to the lighter car.

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Chapter 8

CIRCULAR MOTION

Linear v/s circular motion, circular motion, uniform and non-uniform circular motion, angular velocity, angular acceleration, rigid body motion, centripetal force v/s centrifugal force, banking of curve and advantage, skidding on a curved path.

Motion of a body can be linear or circular. However they differ in number of ways as listed in the table given below:

Linear Motion	Rotational Motion
Displacement x	Angular Displacement θ
Velocity $v = dx/dt$	Angular velocity $\omega = d\theta/dt$
Acceleration = $a = dv/dt$	Angular displacement $\alpha = d\omega/dt$
Mass M	Moment of Inertia I
Force $F = Ma$	Torque $\tau = Ix$
Work $dh = Fds$	Work $W = \tau d\theta$
Kinetic Energy $k = \frac{1}{2}mv^2$	Kinetic Energy $K = \frac{1}{2}I\omega^2$
Power $p = Fv$	Power $P = \tau\omega$
Linear momentum $p = mv$	Angular momentum $L = I\omega$

- **Uniform circular motion:** It describes the motion of a body traversing a circular path at constant speed. Since the body describes circular motion, its distance from the axis of rotation remains constant at all times. Though the body's speed is constant yet its velocity is not constant, velocity being a vector quantity, depends on both the speed of the body and its direction of travel. This changing velocity indicates the presence of an accelerated motion. The centripetal acceleration of constant magnitude is directed at all times towards the axis of rotation. This acceleration is, in turn, produced by centripetal force which is also constant in magnitude and directed towards the axis of rotation.
- In case of rotation around a fixed axis of a rigid body that is not negligibly small compared to the radius of the path, each particle of the body describes a uniform circular motion with the same angular velocity, but with velocity and acceleration varying with the position with respect to the axis.(The magnitude of the angular velocity is the angular speed.)
- **Formulas :** The figure shows the vector relationships for uniform circular motion, vector ù representing the rotation is normal

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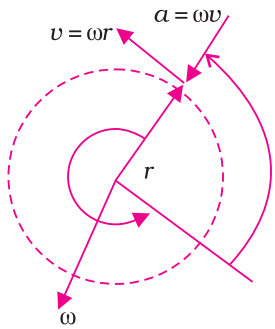
to the plane of the orbit. For motion in a circle of radius r, the circumference of the circle is C = 2π r. If the period for one rotation is T, the angular rate of rotation, also known as angular velocity, ω is :



and the units are radians/second.

$$\omega = \frac{2\pi}{T} = 2\pi f = \frac{\theta}{T}$$

The speed of the object travelling the circle is:

$$v = \frac{2\pi r}{T} = \omega r$$

The angle θ swept out in a time t is :

$\theta = 2\pi f = \omega t$

The angular acceleration, α, of the particle is :

$$\alpha = \frac{d\omega}{dt}$$

In case of uniform circular motion, α will be zero.

The acceleration due to change in the direction is :

$$\alpha = \frac{v^2}{r} = \omega^2 r$$

The centripetal and centrifugal force can also be found out using acceleration:

$$F_c = ma = \frac{mv^2}{r}$$

- The vector relationships are shown in Figure given above. The axis of rotation is shown as a vector ω perpendicular to the plane of the orbit and with a magnitude $\omega = d\theta / dt$. The direction of ω is chosen using the right-hand rule. With this convention for depicting rotation, the velocity is given by a vector cross product as $v = \omega \times r$ which is a vector perpendicular to both ω and r(*t*), tangential to the orbit, and of magnitude ω *r*. Likewise, the acceleration is given by

$\alpha = \omega \times v = \omega(\omega \times r) = \omega^2 r$

- which is a vector perpendicular to both ω and *v*(*t*) of magnitude ω^2 *r* and directed exactly opposite to *r*(*t*).

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- In the simplest case the speed, mass and radius are constant.

Consider a body of one kilogram, moving in a circle of radius one metre, with an angular velocity of one radian per second, then

- The speed is one metre per second.
- The inward acceleration is one metre per square second, v^2/r.
- It is subject to a centripetal force of one kilogram metre per square second, which is one newton.
- The momentum of the body is one $kg \cdot m \cdot s^{-1}$.
- The moment of inertia is one $kg \cdot m^2$.
- The angular momentum is one $kg \cdot m^2 \cdot s^{-1}$.
- The kinetic energy is 1/2 joule.
- The circumference of the orbit is 2π (~6.283) metres.
- The period of the motion is 2π seconds per turn.
- The frequency is $(2\pi)^{-1}$ or $\frac{1}{2\pi}$ hertz (Hz).

- **Rigid body motion :** In the given figure s is arc, r is the radius and θ is the angle.

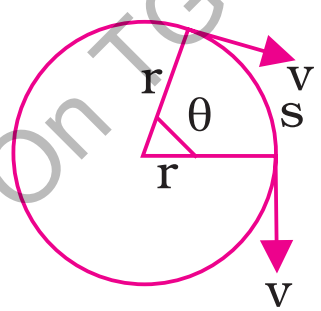
  Angle to be measured in radians: $\theta = s/r$

  Or $\theta = 2\pi r/r = 2\pi$

  $360° = 2\pi$ rad

  So $1° = 0.01745$ rad

  or 1 rad = 57.30^0



- 1rpm = 1 rev/min x $2\pi ra$/rev x 1/60 sec/min = 0.105 rad/sec

Uniform v/s non-uniform circular motion :

S. No.	Uniform Circular Motion	Non-Uniform Circular Motion
1.	Circular motion with constant angular speed.	Circular motion with variable angular speed.
2.	$\alpha = 0$	$\alpha \neq 0$
3.	Work done by tangential force is zero.	Work done by tangential force is not equal to zero.
4.	Revolution of earth in its orbit.	Motion of a body in a vertical circle.

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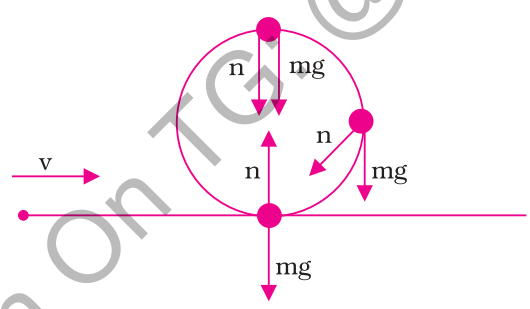
- **Non-uniform circular motion** An object imoving in a circular path with a varying speed, is considered to be in non-uniform circular motion. Since the speed is changing, there is tangential acceleration in addition to normal acceleration.
- In non-uniform circular motion the net acceleration (α) is along the direction of Δv which is directed inside the circle but does not pass through its centre as shown is the figure. The net acceleration may be resolved into two components: tangential acceleration and normal acceleration, also known as the centripetal or radial acceleration. Unlike tangential acceleration, centripetal acceleration is present in both uniform and non-uniform circular motion.
- In non-uniform circular motion, normal force does not always point in the opposite direction of weight. With uniform circular motion, the only force acting upon an object traveling in a circle is the centripetal force. In non-uniform circular motion, there are additional forces acting on the object due to a non-zero tangential acceleration. Although there are additional forces acting upon the object, the sum of all the forces acting on the object will have to be equal to the centripetal force.



Problem : A 900 kg car moving at 10 m/s turn around a cicular path of radius 25.0m. Find the acceleration and net force acting upon the car.

Solution : Given m = 900kg, v= 10.0 m/s R = 25.0 m

$a = v^2/R$

$a = (10\ m/s)^2 / 25.0\ m = 4\ m/s^2$

With F = m . a

$= 900.0\ kg \times 4\ m/s^2 = 3600\ kg\ ms^{-2}$ or 3600 N

Centripetal force v/s centrifugal force :

1. Centrifugal force is the tendency of an object to fly away from the centre of curvature being the inertia of motion but centripetal force is the force that keeps an object moving with a uniform speed along a circular path.

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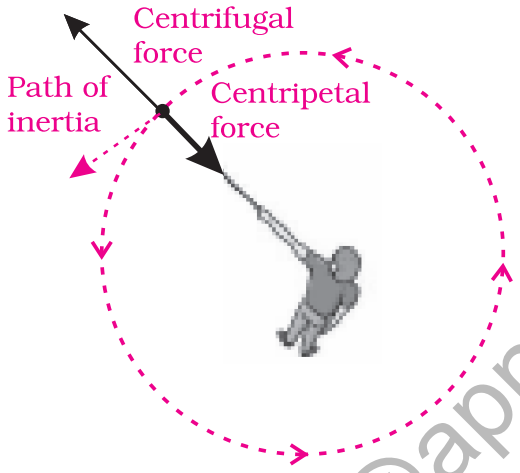
2. Centrifugal force acts along the radius of the circle from the centre towards the object but centripetal force acts along the radius of the circle from the object towards the centre.

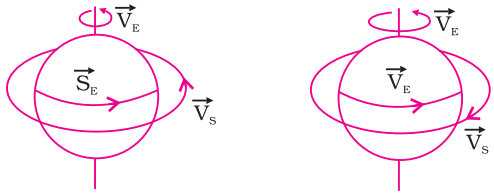


3. Centrifugal force is directed along the radius from the centre towards the object such as the mud flying off a tyre or children being pushed outward on a revolving roundabout but the centripetal force is directed towards the centre of the circle such as a satellite orbiting earth or a planet.

➢ **Circular motion and relative velocity :** If a satellite is moving in the equatorial plane with velocity $\vec{V}_S$ and a point on the earth's surface with velocity $\vec{V}_E$ relative to the centre of earth, the relative velocity of satellite w.r.t. surface of earth is

$$\vec{V}_{SE} = \vec{V}_S - \vec{V}_E$$

If the satellite is moving from west to east, i.e. in the direction of rotation of earth on its axis as shown in figure, its relative velocity. w.r.t earth's surface will be $V_{S.E.} = V_S - V_E$



If the satellite is moving from east to west i.e. opposite to the rotation of earth

$$V_{SE} = V_s - (-V_E) = V_S + V_E$$

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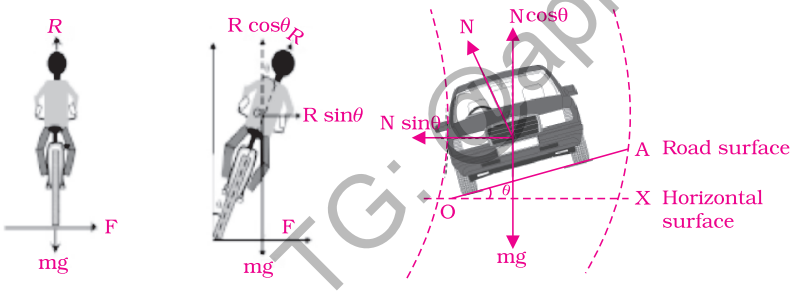
- **Banking of curved roads and tracks and Condition for skidding:** When a car goes round a level curve, the force of friction between the tyres and the road provides the necessary centripetal force. If the frictional force , that acts as centripetal force to keep the body moving along the circular road is not enough to provide necessary centripetal force, the car will skid. In order to prevent skidding , while going round the curved path, the outer edge of the road is raised above the level of the inner edge. This raising is called banking of curved path or roads.
- **Bending of a cyclist round a curve :** The figure shows a cyclist taking a turn on a circular path of radius r. Let *m* be the mass of the cyclist along with the bicycle and *v* be the velocity. When the cyclist negotiates the curve , he bends inwards from the vertical by an angle θ. Let R be the reaction of the ground on the cyclist, be resolved into two components.



  - the component R sinθ, acting towards the centre of the curve providing necessary centripetal force
  - the component *R cos*θ , balancing the weight of the cyclist along with the bicycle, *i.e.*

    $R \sin\theta = mv^2/r$ .....(i)

    $R \cos\theta = mg$ .....(ii)
- Dividing the above equations (i) and (ii)

  $R \sin\theta / R \cos\theta = (mv^2/r)/mg$

  $\tan\theta = \frac{V^2}{rg}$
- Therefore, for less bending of the cyclist, the velocity *v* has to be smaller and radius *r be larger.*
- For a banked road with *h* being the elevation of the outer edge, *sin*θ = *h/I, where I is the width of the raod.*

  $\tan\theta = h/I = v^2/rg$
- Skidding occurs when the centripetal force is greater than the frictional force.
- The similar effect is observed when a car takes a turn on a curved path as shown in the figure.

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Chapter 9

WORK, FORCE AND ENERGY

Energy, different forms of energy, work, law of conservation of energy, relation between kinetic energy and work, sum total of the potential energy stored in a spring, work-kinetic energy theorem, types of contact and non-contact forces, frictional force and power, simple machines.

- **Energy :** It can be defined as the capacity for doing work. The simplest case of mechanical work is when an object is standing still and we force it to move. The energy of a moving object is called kinetic energy. For an object of mass m, moving with velocity of magnitude v, this energy can be calculated from the formula $E = 1/2\ mv^2$.

Types of Energy : There are two types of energy in many forms:

- **Kinetic Energy :** It is the energy possessed by a body in motion.
- **Potential Energy :** It is the energy stored in a body at rest.

Forms of Energy

- **Solar Radiation :** It's the energy possessed by Infrared Heat, Radio Waves, Gamma Rays, Microwaves, Ultraviolet Light, etc.
- **Atomic/Nuclear Energy :** It's the energy released in nuclear reactions. When a neutron splits the nucleus of an atom into smaller pieces, it is called fission. This is the source of energy in nuclear plants. When two nuclei are joined together under fusion, millions of degrees of joules of heat energy is released such as in stars like the sun. In both cases, fusion or fission, some of the matter making up the nuclei is actually converted into energy, matter itself being a form of energy. This concept involves one of the most famous formulas in physics, the formula, $E=mc^2$.
- The formula was discovered by Einstein as part of his "Theory of Special Relativity". In simple words, it means that the energy intrinsically stored in a piece of matter at rest equals its mass times the speed of light squared.
- **Electrical Energy :** All matter is made up of atoms, and each atom is further made up of protons, neutrons and electrons. Electrons orbit around the centre, or nucleus, of atoms while neutrons and protons present in the centre make up the nucleus.
- Some materials, particularly metals, have some electrons loosely attached to their nucleus in the centre. They can easily be made to move from one atom to another if an electric field or voltage is applied to them. When these electrons move among the atoms of matter, a *current* of electricity is created.

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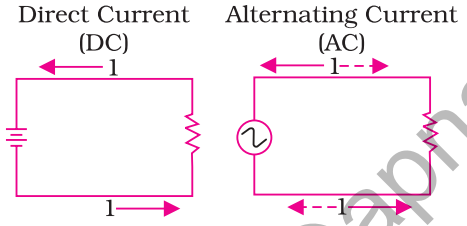
- The electrons pass from atom to atom, pushed by the electric field and by each other (they repel each other because like charges repel), thus creating the electrical current, *i.e.* the electrical energy is really transferred by the chain of repulsive interactions between the electrons down the conductor - not by the transfer of electrons per sec and as the electrons move through a "resistor" in the circuit, they interact with the atoms in the resistor very strongly, causing the resistor to heat up, hence, delivering energy in the form of heat too. (Joule's law of heating) The measure of how well something conducts electricity is called its *conductivity*, and the reciprocal of conductivity is called the *resistance.*



- The generation or use of electric power over a period of time is expressed in kilowatt-hours (kWh, 1kwh= 3.6×10^6J), megawatt-hours (MWh) or gigawatt-hours (GWh).
- **Chemical Energy :** Chemical energy is a form of potential energy related to the breaking and forming of chemical bonds. It is stored in food, fuels and batteries, and is released as the other forms of energy during chemical reactions. Chemical energy is really a form of *microscopic potential energy*, which exists because of the electric and magnetic forces of attraction exerted between the different parts of each molecule, the same attractive forces involved in thermal vibrations. These parts get rearranged in chemical reactions, releasing or adding to this potential energy.
- **Electrochemical Energy :** Consider the energy stored in a battery, is in form of chemical energy such as in a dry cell or storage battery . But as electricity is also involved, the battery is supposed to store energy "electro-chemically". Another electron chemical device is a "fuel-cell" that uses water as the chemical source of energy for the production of hydrogen as a fuel.
- **Electromagnetic Energy (light) :** Consider the energy transmitted to the Earth from the Sun by light (or by any source of light). Light is also called "electro-magnetic radiation". Light is considered as the little packets of energy called *photons* (that is, as particles, instead of waves). The word "photon" has been derived from the word "photo", which means "light". Photons are created when electrons jump to lower energy levels in atoms, and absorbed when

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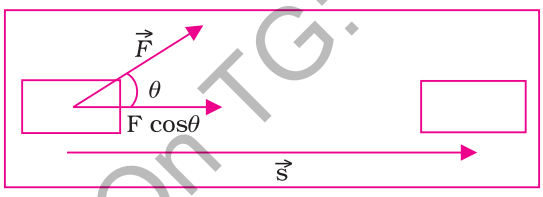
electrons jump to higher levels. Photons are also created when a charged particle, such as an electron or a proton, is accelerated, as for example happens in a radio transmitter antenna.

- **Sound Energy :** Sound waves are compression waves associated with the potential and kinetic energy of air molecules. When an object moves quickly (for example, the head of a drum) it compresses the air near by, giving that air potential energy. That air then expands, transforming potential energy into kinetic energy (moving air). The moving air then pushes on and compresses other air, and so on down the chain leading to the propagation of energy called sound energy.
- **Work :** The work done by an agent exerting a constant force $\vec{F}$ and causing a displacement $\vec{s}$ equals the magnitude of the displacement s times the component of $\vec{F}$ along the direction of s. In the figure below , the work done F is $W = s\,F\cos\theta$
  - If $\vec{s} = 0 \Rightarrow W = 0$ e.g. no work is done while holding a heavy box, or pushing against a wall).
  - $W = 0$ if $\vec{F} \perp \vec{s}$ e.g. no work is done while carrying a bucket of water horizontally).



  - The sign of W depends on the direction of $\vec{F}$ relative to $\vec{s}$: W > 0 when component of $\vec{F}$ along $\vec{s}$ is in the same direction as $\vec{s}$, and W < 0 when it is in the opposite direction. This sign is given automatically if we write θ as the angle between $\vec{F}$ and $\vec{s}$ and write $W = Fs.\cos\theta$.
  - If $\vec{F}$ acts along the direction of $\vec{s}$ then $W = Fs$, since cos θ = cos 0 = 1.
  - Work is a scalar quantity. Its SI units are Joules (J) (1 Joule = 1 Newton metre). In CGS units: 1 erg = 1 dyne cm.
- **Law of conservation of energy :** It states, *"In a closed system, i.e. a system that is isolated from its surroundings, the total energy of the system is conserved"* In SI units, energy has units of *Joules* (1 Joule = 1 kg $m^2 s^{-2}$). However, one form of energy gets transformed into the other.

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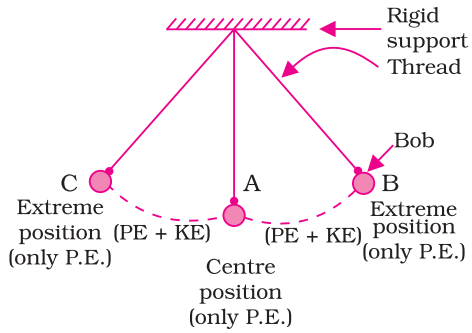

Ex. for law of conservation of Energy

Transformation of energy		
	Equipment/Instrument	**Transformation of Energy**
1.	Microphone	Sound energy into Electrical energy
2.	Dynamo	Mechanical energy into Electrical energy
3.	Loudspeaker	Electrical energy into Sound energy
4.	Solar Cell	Solar energy into Electrical energy
5.	Electirc cell	Chemical energy into Electrical energy
6.	Electric motor	Electrical energy into Mechanical energy
7.	Musical instruments	Mechanical energy into Sound energy
8.	Bulb/Tube	Electrical energy into Light energy
9.	Heater	Electrical energy into Thermal energy
10.	Candle	Chemical energy into Light and Thermal energy
11.	Coal	Chemical energy into Thermal energy
12.	Heat Engine	Thermal energy (Heat energy) into Mechanical energy

- For a closed thermodynamic system, the law of conservation of energy is equivalent to the first law of thermodynamics. It may be stated as :

  $\delta Q = dU + \delta W$ or equivalently, $dU = \delta Q - \delta W$

  where δQ is the quantity of energy added to the system by a heating process, δW is the quantity of energy lost by the system due to work done by the system on its surroundings and δU is the change in the internal energy of the system.

- **Work–kinetic energy theorem :** Consider again a particle of mass m moving in one spatial dimension. If force F is needed to move the particle from position x_1 to position x_2 then *mechanical*

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work w has been done on the particle. Since *F* can be a function *F(x)* of the general definition of work being the area under the force function *F(x)* between x_1 and x_2, *i.e.* the integral

$$W = \int_{x_1}^{x_2} f(x)(dx)$$

However, since = $f(x) = -dv/dt$

$$W = \int_{x_1}^{x_2} -\frac{dv}{dx}dx$$

$$W = -\int_{x_1}^{x_2} dx = -[(v(x_2) - v(x_1)]$$

$$\boxed{W = x(x_1) - (x_2)}$$

- If the velocity of the particle at x_1 is v_1 and at x_2, it is v_2, then by energy conservation

$$\frac{1}{2}mv_1^2 + v(x_1) = \frac{1}{2}mv_2^2 + v(x_2)$$

Rearranging this gives

$$v(x_1) - v(x_2) = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_1^2$$

Hence, the work $W = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2$ is also equal to the change in kinetic energy, a result known as the *work-kinetic energy theorem.*

- **Relation between KE and W :** The work done on an object by a net force equals the change in kinetic energy of the object:
  $W = KE_f - KE_i$. or $K.E._2 - K.E_1$
- This relationship is called the work-energy theorem.

For $\vec{s}$ parallel to $\vec{F}$:

$W = Fs \Rightarrow W = (ma)s$ (by Newton's second law).

From the third equation of motion:

$= (v^2 - v_0^2)/2$

$\Rightarrow W = 1/2m(v^2 - v_0^2) = K.E_f - K.E_i$

Note: If

- the speed of an object increases ($v_f > v_i$) $\Rightarrow W > 0$.
- $W < 0$ then the object is doing work on the agent exerting the net force.

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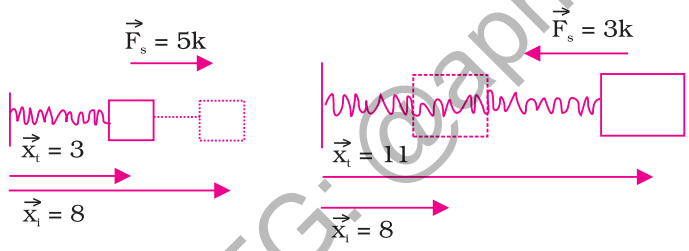
- **Potential Energy Stored in a Spring :** The spring constant, k, is a measure of the stiffness of a spring (large $K \rightarrow$ stiff spring, small $k \rightarrow$ soft spring).
- To compress a spring by distance Δx, force $F_{ext} = k\Delta x$ needs to be applied. According to Newton's 3rd law, if a spring is held in a compressed position then it exerts force $F_s = -k\Delta x$. This is called a linear restoring force because the force is always in the *opposite direction from the displacement*. The sign of F_s shows that the spring resists attempts to compress or stretch it, therefore, F_s is a restoring force.
- For Example : In figure $\Delta x = x_f - x_i = -5$ which gives $F_s = -k(-5) = 5k$. This force is positive and, therefore, directed to the right. This means that the spring resists the compression. In figure $\Delta x = x_f - x_i = 3$ which gives $F_s = -3k$. The negative sign indicates that the force is to the left and that the spring resists the stretching.



Compressed spring **Stretched spring**

- The farther the spring is compressed or stretched the greater is the restoring force.
- With $x_i = 0$ and $x_f = x$ which gives $F_s = -kx$ is Hooke's law of elasticity.
- To find the potential energy stored in a compressed (or stretched) spring, one calculates the work to compress (or stretch) the spring. The force to compress a spring varies from $F_{ext} = F_0 = 0$ (at $x_i = 0$), to $F_{ext} = F_x = kx$ (at $x_f = x$). Since force increases linearly with x, the average force that must be applied is

  $F_{ext} = ½ (F_o + F_x) = ½ kx$
- The work done by $F_{ext} = W = F_{ext}\ x = ½ kx^2$, *is the* work done in the spring stored as potential energy.

  $PE_s = ½ kx^2$

Note :

- $PE_s = 0$ when $x = 0$ (at equilibrium).
- PE_s always > 0 when the spring is not in equilibrium.
- PE_s is the same if $x = \pm\ x_f$ (the same PE_s for equal expansion or compression).

- **Problem :** How much work is done by an applied force to lift a 15 Newton block 3.0 metres, vertically up at a constant speed?

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Solution : To lift a 15 Newton block at constant speed, 15 N of force must be applied to it (Newton's law). Thus

W = (15 N) x (3 m) x cos 0^0 = 45 Joules

Problem : A student with a mass of 80.0 kg runs up three flights of stairs in 12.0 sec. The student has gone a vertical distance of 8.0 m. Determine the amount of work done by the student to elevate his body to this height. Assume that his speed is constant.

The student weighs F_{grav}= 80 kg x 9.8 m/s/s = 784 N

- To lift a 784 Newton person at constant speed, 784 N of force must be applied to it (Newton's laws of motion). The force is up, the displacement is up, and so the angle theta in the work equation is 0 degree. Thus,

  w = Fs cosθ

  W=784 N × 8m × cos0° (cos0° = 1)

  W = 6272 Joules

- **Force and its types :** Force is a push or pull acting upon an object as a result of its interaction with another object. There are a variety of forces placed into two broad category, on the basis of whether the force has resulted from the contact or non-contact.
- **Non-contact forces :** The force which acts on an object without coming physically in contact with it is called non-contact force. All four known fundamental interactions are non-contact forces.
- **Gravity :** It's the force of attraction which is exerted on all bodies that have mass. The force exerted on each body by the other through weight is proportional to the mass of the first body times the mass of the second body divided by the square of the distance between them.
- This force actually refers to the weight of the object. All objects upon the earth experience a force of gravity that is directed "downward" towards the centre of the earth. The force of gravity on the earth is always equal to the weight of the object as found by the equation:

  F_{grav} = m x g

  where g = 9.8 N/kg (on the Earth) and m = mass (in kg)

- **Normal force :** It is the support force exerted upon an object that is in contact with another stable object. For example, if a book is resting upon a surface then the surface is exerting an upward force upon the book in order to support the weight of the book. On occasions, a normal force is exerted horizontally between two objects that are in contact with each other. For instance, if a person leans against a wall, the wall pushes horizontally on the person.
- **Electromagnetism :** It's the force that causes the interaction between electrically charged particles; the areas in which this happens are called electromagnetic fields. Examples of this force include: electricity, magnetism, radio waves, microwaves, infrared, visible light, X-rays and gamma rays. Electromagnetism mediates all chemical, biological, electrical and electronic processes.

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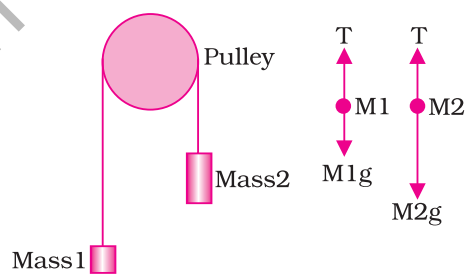
- **Strong nuclear force :** Unlike gravity and electromagnetism, the strong nuclear force is a short distance force that takes place between fundamental particles within a nucleus. It is charge independent and acts equally between a proton and a proton, a neutron and a neutron, and a proton and a neutron. The strong nuclear force is the strongest force in nature, However, its range is small (acting only over distances of the order of 10^{-15} m). The strong nuclear force mediates both nuclear fission and fusion reactions.
- **Weak nuclear force :** This force mediates the β decay of a neutron, in which the neutron decays into a proton and in the process emits a β particle and an uncharged particle called a neutrino. As a result of mediating the β decay process, the weak nuclear force plays a key role in supernova. Both these strong and weak forces form an important part of quantum mechanics.

Contact forces : These forces include

- **Applied force :** It is a force applied on an object by a person or another object. If a boy pushes a desk across the room or hammers a nail, then there is an applied force acting upon the object.
- **Air resistance force :** It is a special type of frictional force that acts upon objects as they travel through the air. The force of air resistance is often observed to oppose the motion of an object. This force will frequently be neglected due to its negligible magnitude (and due to the fact that it is mathematically difficult to predict its value). It is most noticeable for objects that travel at high speeds (e.g., a skydiver or a downhill skier) or for objects with large surface areas.
- **Tension force :** It is the force that is transmitted through a string, rope, cable or wire when it is pulled tight by forces acting from opposite ends. The tension force is directed along the length of the wire and pulls equally on the objects on the opposite ends of the wire.



- **Spring force :** It is the force exerted by a compressed or stretched spring upon any object that is attached to it. An object that compresses or stretches a spring is always acted upon by the force that restores the object to its rest or equilibrium position. For most springs magnitude of the force is directly proportional to the amount of stretch or compression of the spring.

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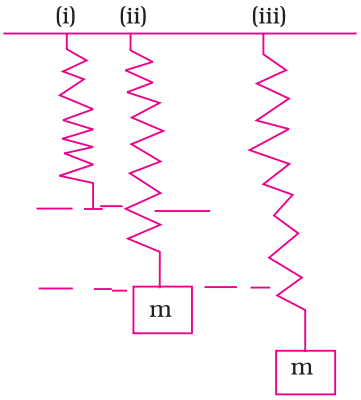
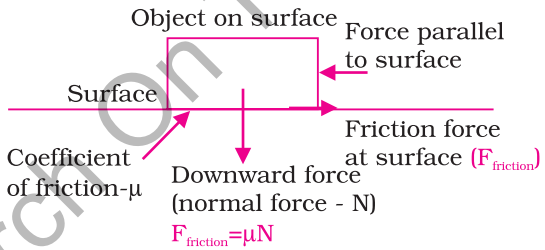


- **Frictional force :** It is the force exerted by a surface as an object moves across it or makes an effort to move across it. There are at least two types of friction force - sliding and static friction. The frictional force often opposes the motion of an object, e.g., if a book slides across the surface of a desk then the desk exerts a frictional force in the opposite direction of its motion. Friction results from the two surfaces being pressed together closely, causing intermolecular attractive forces between the molecules of different surfaces. As such, friction depends upon the nature of the two surfaces and the degree to which they are pressed together. The maximum amount of frictional force that a surface can exert upon an object is



$F_{frict} = \mu \times F_{norm}$, where μ is the coefficient of friction.

- The kinetic friction can be sliding or rolling, and fluid friction.

Static friction > Sliding friction > Rolling friction > Fluid friction.

- **Factors affecting force of friction :** The different factors which affect the force of friction include:
  - Mass (and weight): As it increases, the force of friction increases too such as the force required to overcome friction (in order to pull the object forward) increases.
  - Nature of surface: As the roughness of the surface increases, the force of friction also increases. Therefore, the force needed to overcome friction (pull the object forward) increases.

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- The force of friction is not affected by the amount of surface area of an object but on the surface area in contact. Therefore in kinetic friction, the rolling friction is less than sliding friction.

➢ **Advantages and disadvantages of friction :** Friction considered as the necessary evil has the major disadvantages which include :

- wastage of energy such as the heat generated by a machine. Therefore, practically no machine can have a 100% efficiency.
- loss of matter such as wearing off the soles of shoes with time while they protect us from slipping or sliding too.

➢ The major advantage includes the easy conversion of one form of energy into another such as when lighting a matchstick or reduction in speed on applying brakes or changing the direction of motion by turning the steering wheel.

Phenomenon		
S.No	Phenomenon	Energy (J)
1.	Energy spent in turning a page	$\approx 10^{-3}$
2.	Work done by human heart in a beat	≈ 0.5
3.	Daily food intake of a person	$\approx 10^{7}$
4.	Annual solar energy incident on earth	$\approx 5\times10^{24}$
5.	Rotation energy of earth	$\approx 1\times10^{29}$
6.	Big Bang in orgin of Universe	$\approx 1\times10^{68}$

➢ **Power :** Power is the rate at which work is done. It is the work/time ratio. Mathematically, it is computed using the equation:

Power = Work / Time, *i.e.* P= W/T

➢ The standard metric unit of power is the Watt. It is equivalent to a unit of work done in a unit time, *i.e.* it is also equivalent to a joule/second (Js^{-1}).

➢ For historical reasons, the *horse power* is occasionally used to describe the power delivered by a machine. 1 horsepower = 746 watt.

➢ The commercial unit of power is KWh. It is equal to 3.6×10^{6} J.

Problem : Find the power of a boy who can elevate his 80 kg body up the 2.0 metre stairwell in 1.8 seconds.

Solution : Power = $\frac{\text{Work}}{\text{Time}} = \frac{Fs}{t}$

$$= \frac{80\text{kg} \times 9.8\ \text{m/s}^2 \times 2.0\text{m}}{1.8\text{s}} = 871\ \text{W}$$

➢ The expression for work is force x displacement, the expression for power can also be rewritten as (force x displacement)/time. Since the expression for velocity is displacement/time, the expression

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for power can be rewritten once more as force x velocity as given below.

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force x Displacement}}{\text{time}}$$

Power = Force x Velocity

Problem : An escalator is used to move 20 passengers every minute from the first floor of a departmental store to the second. The second floor is located 5.20 metres above the first floor. The average passenger's mass is 54.9 kg. Determine the power requirement of the escalator in order to move this number of passengers in this amount of time.

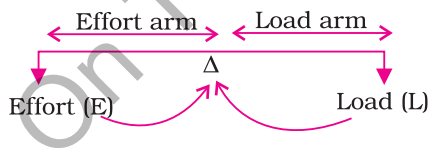
$W_{1\ passenger} = F \times d$

$W_{1\ passenger} = (54.9\ kg \times 9.8\ m/s^2) \times 5.20\ m = 2798\ J$

$W_{20\ passengers} = 55954\ J$

$P = W_{20\ passengers}\ /\ time = (55954\ J)\ /\ (60\ s) = 933W$

- **Simple machine :** It is a device to do useful work using minimum effort. The work done is called load. A machine in which no part of the work done on the machine is called an ideal machine, *i.e.* work output is equal to work input. However, partically no such machine is possible.
- **Levers and their classes :** A lever is a simple machine most commonly used in the daily life. It is simply a rod which turn about a fixed point called the fulcrum.



Load × Load arm = Effort × Effort arm.

- **Class one lever :** It's the lever in which the fulcrum is in between the load and the effort. It's mechanical advantage can be greater than 1, equal to 1 or less than one. e.g. see saw, a pair scissors, pair of pliers, crowbar, common balance, oars of a rowing boat, spoon used to open a bottle lid, handle of a hand pump etc.
- **Class two lever :** It's the lever in which is that the load is in between the fulcrum and effort. It's mechanical advantage the ratio of load to effort is always greater then one E.g.: nut cracker, wheel barrown, paper cutter, lemon squeezer, bottle opener, etc.
- **Class three lever :** It's the lever in which the effort is in betwen the fulcrum and the load. It's mechanical advantage is always less than one. e.g. : a pair of tongs, sugar tongs, knife, forceps spade used for lifting coal, forearm of a person holding a load, etc.

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Chapter 10

GRAVITATION

Universal law of gravitation, acceleration due to gravity, changing value of g on earth w.r.t. distance from equator and altitude from sea level, Kepler's laws of planetary motion, satellites and their types, orbital velocity, acceleration of a revolving satellite, energy of satellite and orbital period.

- **Universal law of gravitation :** According to this law the force of gravity between any two spherical objects of uniform density is directly proportional to the product of their masses, and inversely proportional to the square of the distance between their centre, *i.e.* if m_1 and m_2 are the masses of two objects with their centres separated by a distance d, then the gravitational force (*F*) between them is given by the relation

$$F = G\frac{m_1 m_2}{d^2}$$

where G is a constant that depends on the units specified for m_1, m_2, d and f. It is also called the universal gravitational constant with the value 6.674×10^{-11} N·m² kg⁻².

- **Problem :** Find the force of gravitational attraction between the earth (m = 5.98 x 1024 kg) and a 70 kg physics student if the student is in an airplane at 40,000 feet above the earth's surface.

Solution : The position of the student would place him at a distance of 6.39×10^6 m from the earth's centre.

Substituting the known values of G (6.673×10^{-11} N m²/kg²), m_1 (5.98×10^{24} kg), m_2 (70 kg) and d (6.39×10^6 m) into the equation and solving for F_{grav}

$$F = \frac{6.673 \times 10^{-11}\ Nm^2/kg^2 \times 5.98 \times 10^{24kg} \times 70kg}{(6.39 \times 10^{-4})^2}$$

$$= 684N$$

- **The Value of g depends on location :** The value of g is location-dependent. When both the expressions for the force of gravity are set equal to each other,

$$m.g = \frac{G.M._{earth} \times m}{d^2}$$

$$g = \frac{G.M._{earth}}{d^2}$$

- The above relation clearly indicates that the acceleration of gravity is dependent upon the mass of the earth (approx. 5.98×10^{24} kg) and the distance (d) that an object is at from the centre of the earth. If the value 6.38×10^6 m (a typical earth radius value) is used for the distance from the earth's centre, then g is calculated to be 9.8 m/s².

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- **Gravitational potential energy :** The gravitational potential energy (u) of a point mass m placed in a gravitational field of mass M is given by the work done in moving the point mass in from infinity to the point (specific), *i.e.* at distance R from the point mass M.

  u = mV = m (–GM/r) = (GMm/(r)

  The change in potential energy when a point mass m is moved vertically upwards by height *h* from the earth's surface, $\Delta v = \frac{mgh.R}{R+h}$

  when h << R : $\Delta v = \left(\frac{mgh}{1+(h/R)}\right)$ = mgh.

  h>> Ri : $\Delta u = \left(\frac{mgh}{1+(h/R)}\right)$ = mgR

- **Problem :** Find the value of g if an object is moved further from the earth's centre to two earth-radii from the centre of the earth.

  Solution : The object has been moved by two times of 6.38×10^6m

  At twice the distance from the centre of the earth

  $$g = \frac{6.67 \times 10^{-1}\ N.m^2/kg^2 \times (5.98 \times 10^{24} kg)}{(1.276 \times 10^7 m)} = 2.45\ m/s^2$$

- Calculated value of 'g' for different planets

Acceleration of gravity value for various planets

Planet	Radius (m)	Mass (kg)	g (m/s2)
Mercury	2.43×10^6	3.2×10^{23}	3.61
Venus	6.073×10^6	4.88×10^{24}	8.83
Mars	3.38×10^6	6.42×10^{23}	3.75
Jupiter	6.98×10^7	1.901×10^{27}	26.0
Saturn	5.82×10^7	5.68×10^{26}	11.2
Uranus	2.35×10^7	8.68×10^{25}	10.5
Neptune	2.27×10^7	1.03×10^{26}	13.3
Pluto	1.15×10^6	1.2×10^{22}	0.61

- **Variations in values of g on earth :** The variation in value of g with distance follows an inverse square law where g is inversely proportional to the distance from the earth's centre. This inverse square relationship means that as the distance is doubled, the value of g decreases by a factor of 4. As the distance is tripled, the value of g decreases by a factor of 9. and so on.
- The value of g decreases with increasing height from the sea level.
- The value of g decreases with increasing depth from the sea level.
- The value of g increases moving away from the equator to poles. It is maximum at the poles and minimum at equator. At sea level, the difference is 1.80 cm s^{-2}. Therefore, when a body of mass m is moved from the equator to either of the poles, the weight of the body increases with the increasing value of g by $m(g_p - g_e)$.

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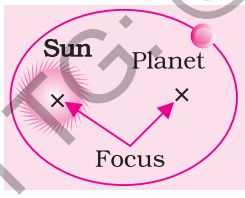
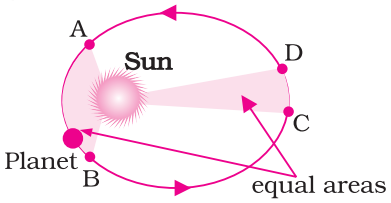
- If the earth stops rotating about its axis, the value of g at the equator will increase by about 0.35 % but at the poles will remain unchanged.
- If the earth starts rotating at the angular speed of about 17 times of its present value, there will be weightlessness on the equator but g at the poles will remain unaffected. In such a case, the duration of the day will be reduced to about 84 minutes.
- **Kepler's laws of planetary motion :** Kepler developed his laws empirically from observation, as opposed to deriving them from some fundamental theoretical principles. About 30 years after Kepler had died, Isaac Newton managed to derive Kepler's Laws from basic laws of gravity.

  Law 1. The orbits of the planets are ellipses, with the Sun at one focus.
- Any ellipse has two geometrical points called the foci (focus for singular). There is no physical significance of the focus without the Sun but it does have mathematical significance. The total distance from a planet to each of the foci added together is always the same regardless of where the planet is in its orbit. The importance of this is that by not assuming the orbits are perfect circles, the accuracy of predictions in the Sun-centered theory was (for the first time) greater than those of the Earth-centered theory.



Law 2. The line joining a planet to the Sun sweeps out equal areas in equal times as the planet travels around the ellipse.



- In any given amount of time, 30 days for instance, the planet sweeps out the same amount of area regardless of which 30-day period you choose. Therefore the planet moves faster when it is nearer the Sun and slower when it is farther from the Sun. A planet moves with constantly changing speed as it moves about its orbit. The fastest a planet moves is at perihelion (closest) and the slowest is at aphelion (farthest).

  Law 3. The square of the total time period (T) of the orbit is proportional to the cube of the average distance of the planet to the Sun (R).

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- This law is sometimes referred to as the law of harmonies. It compares the orbital time period and radius of an orbit of any planet, to those of the other planets. The discovery Kepler made is that the *ratio* of the squares of the revolutionary time periods to the cubes of the average distances from the Sun, is the same for every planet.
- **Satellites and their types :** A satellite is a small or large body that revolves round a massive body. A satellite can be natural like moon is the only satellite of the earth or an artificial, man-made satellites. The artificial satellites are further classified according to the type of orbits they revolve in. There are four types of orbits associated with satellites, and the type of orbit dictates the satellite's use.

1. **Low Earth Orbits :** Satellites in lower Earth orbits are normally military reconnaissance satellites that can pick out tanks from 160 km above the earth. They orbit the earth very quickly, one complete orbit normally takes 90 minutes. However, these satellites have very short lifetime in the order of weeks compared with decades for geostationary satellites. Simple launch vehicles are used to place these satellites of large masses into the orbit.
2. **Sun-Synchronous orbits :** These are meteorological satellites often placed in a sun-synchronous or helio-synchronous orbit. These satellites are in polar orbits. The orbits are designed so that the satellite's orientation is fixed relative to the Sun throughout the year, allowing very accurate weather predictions to be made. Most meteorological satellites predicting weather conditions orbit the earth 15 -16 times per day.
3. **Geosynchronous satellites :** Earth-synchronous or geosynchronous satellites are placed into orbit so that their period of rotation may exactly match the earth's rotation. They take 24 hours to make one revolution. However, the plane of orbit for these satellites is generally not the equatorial plane. These satellites are used for communications at high latitudes, particularly in Russia and Canada. The orbits are called Molniya orbits. The satellites are placed in highly elliptical orbits which enable them to appear to hover above one point on the earth for most of the day. In twenty-four hours, they move over the earth in a figure of eight pattern centered on a fixed longitude, moving slowly where they can be useful and quickly where they are of little use.
4. **Geostationary satellites** : The majority of communication satellites are, in fact, geostationary satellites. Geostationary satellites take 24 hours to complete a rotation. However, geostationary satellites are positioned directly over the equator and their path follows the equatorial plane of the earth. As a result, geostationary satellites don't move North or South during the day and are permanently fixed above one point on the equator of the Earth.

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- Most video or T.V. communications systems use geostationary satellites. Geosynchronous and geostationary satellites typically orbit at 35,788 km (22,238 miles) above the surface of the earth (42,000 km from its centre).
- **Orbital velocity :** Consider a satellite with mass M_{sat} orbiting a central body with a mass of $M_{Central}$. The central body could be a planet, the sun or some other large mass capable of causing sufficient acceleration on a less massive nearby object. If the satellite moves in circular motion then the net centripetal force acting upon this orbiting satellite is :

$$F_{net} = \frac{M_{sat}.v^2}{R}$$

- This net centripetal force is the result of the gravitational force that attracts the satellite towards the central body and is

$$F_{grav} = \frac{G.M_{sat}.M_{Central}}{R^2}$$

$$\text{Since } F_{grav} = F_{net} = \frac{M_{sat.} x\ v^2}{R^2} = \frac{G.M_{sat.} x\ M_{Central}}{R^2}$$

or,

$$V^2 = \frac{G \times M_{Central}}{R}$$

$$V = \sqrt{\frac{G \times M_{Central}}{R}} \quad \text{.... (i)}$$

where G is 6.673×10^{-11} Nm^2/kg^2, $M_{central}$ is the mass of the central body about which the satellite orbits, and R is the radius of orbit for the satellite.

- **Acceleration of an orbiting satellite :** The acceleration value of a satellite is equal to the acceleration of the gravity of the satellite at whatever location that it is orbiting, *i.e.* $g = (G \bullet M_{central})/R^2$
- Thus, the acceleration of a satellite in circular motion about some central body is given by the following equation

$$a = \frac{G \times M_{Central}}{R^2} \quad \text{...(ii)}$$

where G is 6.673×10^{-11} Nm^2/kg^2, $M_{central}$ is the mass of the central body about which the satellite orbits, and R is the average radius of orbit for the satellite.

- **Orbital Period :** The period of a satellite (T) and the mean distance from the central body (R) according to Kepler's 3rd law are related by the following equation :

$$\frac{T^2}{R^3} = \frac{4\pi^2}{M_{Central}} \quad \text{...(iii)}$$

where T is the period of the satellite, R is the average radius of orbit for the satellite (distance from centre of the central planet), and G is $6.673 \times 10^{-11} N \bullet m^2/kg^2$.

- In none of three equations (i), (ii) and (iii) - the period, speed and the acceleration of an orbiting satellite are dependent upon the mass of the satellite *i.e.* variable $M_{satellite}$ is not present. This clearly indicates that period, speed and acceleration of a satellite are only

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dependent upon the radius of the orbit and the mass of the central body that the satellite is orbiting but not on the mass of the satellite. Just as in the case of the motion of projectiles on earth, the mass of the projectile has no effect upon the acceleration towards the earth and the speed at any instant. When air resistance is negligible and only gravity is present, the mass of the moving object becomes a non-factor. Such is the case of orbiting satellites.

- **Escape velocity:** Escape velocity is the speed that an object needs to be travelling to break free of a planet or the moon's gravity well and leave it without further propulsion. For example, a spacecraft leaving the surface of the earth needs to be going 7 miles per second, or nearly 25,000 miles per hour to leave without falling back to the surface or falling into the orbit. With

$$V = \sqrt{\frac{G \times M}{R}} = \sqrt{2gr}$$

where V_{esc} is the escape velocity, G is the gravitational constant, M is the mass of the body being escaped from, r is the distance between the centre of the body and the point at which escape velocity is being calculated, g is the gravitational acceleration at that distance, and ì is the standard gravitational parameter.

- The escape velocity at a given height is $\sqrt{2gR}$ or $\sqrt{(2GM / R)}$ times the speed in a circular orbit at the same height. This corresponds to the fact that the potential energy with respect to infinity of an object in such an orbit is minus two times its kinetic energy, while to escape the sum of potential and kinetic energy needs to be at least zero. For a body with a spherically-symmetric distribution of mass, the escape velocity V_{esc} from the surface (m/s) is approximately 2.364×10^{-5} $m^{1.5}kg^{-0.5}s^{-1}$ times the radius r (in metres) times the square root of the average density ρ (in kg/m^3), or : $V \approx 2.364 \times 10^{-5}\ r\sqrt{\rho}$ The escape velocity from the Earth is 11 184 *m/s*, or approximately 11.2*km/s and for moon is 2.4 km/sec.*

  The escape velocity is independent of the mass, size and shape of the body and its direction of projection.

- **Satellite and energy :** The work-energy theorem is expressed in equation form as KEi + PEi + Wext = KEf + PEf
- The W_{ext} is the amount of work done by external forces. For satellites, the only force is gravity. Since gravity is considered an internal (conservative) force, the W_{ext} term is zero. Hence, $kE_i + kE_i = KE_f + PE_f$, *i.e.* the total mechanical energy of the system is conserved with the sum of kinetic and potential energies remaining unchanged. As a satellite orbits the earth, its total mechanical energy remains the same. Whether in circular or elliptical motion, there are no external forces capable of altering its total energy.

  Problem : If a geostationary satellite is to orbit in 24 hours then how high above the earth's surface it must be placed when M_{earth}= 5.98×10^{24} kg and $R_{earth} = 6.37\ 5\ 10^6$ m.

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Solution : T = 86400 s, $M_{earth} = 5.98 \times 10^{24}$ kg, $R_{earth} = 6.37 \times 10^6$ m
$G = 6.673 \times 10^{-11}$ N m²/kg²

$$\frac{T^2}{R^3} = \frac{4\pi^2}{M_{Central}}$$

Or $R^3 = [\ (T^2 \times G \times M_{central})\ /\ (4\pi^2)\ ]$

$R^3 = [\ ((86400\ s)^2 \times (6.673 \times 10^{-11}\ N\ m^2/kg^2) \times (5.98 \times 10^{24}\ kg)\ )\ /\ (4\ (3.1415)^2)\ ]$

$R^3 = 7.54 \times 10^{22}\ m^3$

Or $R = 4.23 \times 10^7$ m

- Radius of the orbit indicates the distance that the satellite is from the centre of the earth. Now that the radius of orbit has been found, the height above the earth can be calculated. Since the earth's surface is 6.37 x 10^6 m from its centre (that's the radius of the earth), the satellite must be at a height of

  4.23×10^7 m – 6.37×10^6 m = 3.59×10^7m

  So, the height of the satellite is 3.59×10^7m.

- **Some facts about satellites motion :**
  - Escape velocity and orbital velocity of a satellite are related as; $V_{es} = \sqrt{2V_0}$, *i.e.* if speed of statellite is increased by 41.4%, its kinetic energy will increase by 100% for it to escape out to an infinite distance.
  - In an orbit, the magnitude of total energy equals to the magnitude of its kinetic energy.
  - The total energy of a body in the orbit is always in negative, the body being bound to earth.
  - With increasing radius of orbit, potential energy increases and kinetic energy decreases.
  - When a satellite is placed in an orbit with the velocity V then the velocity V_o with which satellite revolves around the earth in circular orbit of radius r is $V_O = \sqrt{(GM/r)}$.

    Earth as inertial frame of reference : Earth is revolving around the sun. Therefore, it possesses centripetal acceleration. Rherefore, it should be treated as non-inertial frame of reference. However, value of centripetal acceleration of earth,

$$a = \frac{V^2}{R} = \omega^2 R = \left(\frac{2\pi}{T}\right)^2 R = \frac{4\pi^2 R}{T^2}$$

Putting R = 1 A.U. = 1.496×10^{11}m and

$$T = 365\frac{1}{4}\text{ days} = \frac{1461}{4} \times 24 \times 60 \times 60\text{ sec}$$

$= 3.16 \times 10^7$ sec.

$$\therefore\ a = 4 \times \frac{22}{7} \times \frac{22}{7} \times \frac{1.496 \times 10^{11}}{(3.16 \times 10^7)^2} = 0.006\ m/s^2 a$$

It is negligibly small compared to acceleration due earth is considered as an inertial frame.

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Chapter 11

ELASTICITY

PHYSICS

Elasticity, Hooke's law, Young's modulus, Modulus of rigidity, Bulk modulus of elasticity, elastic limit of materials, stress-strain relationship, Poisson's ratio, surface tension, capillarity, viscosity, Bernoulli's principle and its applications, Sol-gel processing of nano-particles.

Characteristics of a solid : A solid is characterized by **:**

- Malleability : The ability to be hammered into thin sheets.
- Ductility : The ability to be stretched into thin wire.
- Elasticity: The ability to be stretched and then returning to original position after the removal of deforming force.
- Brittleness: The ability of a solid to break.
- Hardness: The ability to resist stretching.
- Tensile strength : The ability to resist breaking under pressure.

- **Elasticity :** It refers to the ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed. A body with this ability is said to behave (or respond) elastically.
- To a greater or lesser extent, most solid materials exhibit elastic behaviour, but there is a limit to the magnitude of the force and the accompanying deformation within which elastic recovery is possible for any given material. This limit is called the elastic limit.
- **Elastic limit :** It refers to the maximum stress or force per unit area within a solid material that can arise before the onset of permanent deformation. Stress beyond the elastic limit causes a material to yield or flow. For such materials the elastic limit marks the end of elastic behaviour and the beginning of plastic behaviour.
- For most brittle materials, stresses beyond the elastic limit result in fracture with almost no plastic deformation.
- **Types of deformation :** There are broadly two types of deformation :

1. **Elastic deformation :** It occurs when after the removal of stress, the material returns to the dimension it had before the load was applied. The deformation is reversible and non-permanent.
2. **Plastic deformation :** It occurs when a large stress is applied to a material. The stress is so large that when removed, the material does not spring back to its previous dimension. There is a permanent, irreversible deformation. The minimal value of the stress which produces plastic deformation is known as the *elastic limit* for the material.

- A spring is always designed and specified so that it only experiences elastic deformation when built into a machine under normal operation.
- **Hooke's law :** Robert Hooke in the 17th century noticed and hence, proposed that the stress v/s strain curve for many materials has a linear region. Within certain limits, the force required to stretch an elastic object such as a metal spring is directly proportional to the extension of the spring. The law is commonly expressed as :

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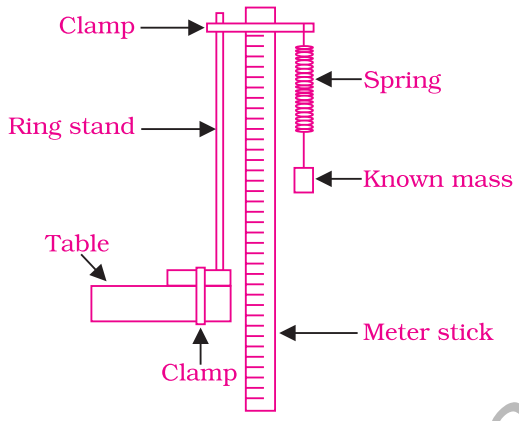

$$F = -kx$$

- Where F is the force, x is the length of extension/compression and k is a constant of proportionality known as the *spring constant F*, is usually expressed in N/m.
- The negative sign is customarily added to signify that the *restoring force* due to the spring is in the opposite direction to the force which caused the displacement. Pulling down on a spring will cause an extension of the spring downward, which will in turn result in an upward force due to the spring.
- When calculating x, it is important to remember that the spring itself also has some nominal length L_0. The total length L of a spring under

— extension is equal to the nominal length plus the extension, $(L = L_0 + x)$

— compression is equal to the nominal length minus compression, $(L = L_0 - x)$.

Problem : A 75 kg person stands on a compression spring with spring constant 5000 N/m and nominal length 0.25 m. What is the total length of the loaded spring ?

Solution : Using Hooke's law, the extension,

$$x = F/K$$

or $$x = mg/K = 0.15 \text{ m}$$

i.e. $$x = \frac{75\text{kg} \times 9.8 \text{ m/s}}{5000\text{N/m}} = 0.15 \text{ m}$$

We now subtract this from the nominal length of the spring:

$$L = L_0 - x = 0.25 - 0.15 \text{ m} = 0.10 \text{ m}$$

- **Cause of elasticity :** The elasticity of different materials arises from short-range interatomic forces that, when the material is unstressed, maintains the atoms in regular patterns. Under stress the atomic bonding can be broken at quite small deformations. By contrast, at the microscopic level, rubber like materials and

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other polymers consist of long-chain molecules that uncoil as the material is extended and recoil in elastic recovery but upto a certain limit.

- **Elastic modulus :** Strain refers to a change in some spatial dimension (length, angle or volume) compared to its original value and stress refers to the cause of the change (a force applied to a surface).
- The coefficient that relates a particular type of stress to the strain that results is called an elastic modulus (plural, moduli). Elastic moduli are the properties of materials, not objects. There are three basic types of stress and three associated moduli.
- **Young's modulus :** It stands for the elastic response of materials such as steel and bone typified by a linear relationship between the tensile stress (tension or stretching force per unit area of cross section of the material), σ , and the extension ratio (difference between extended and initial lengths divided by the initial length), *e*. In other words, σ is proportional to *e*, this is expressed as $\sigma = Ee$, where *E*, the constant of proportionality, is called Young's modulus which is defined as the ratio of normal stress to the longitudinal strain within elastic limit.

$$i.e.\ \gamma = \frac{\text{Normal stress}}{\text{Longitudinal Strain}} = \frac{F/A}{\Delta L/L} = \frac{FL}{A.\Delta L}$$

where F is the normal force applied at the end of its wire, A is the area of cross section πr^2. ΔL is the extension produced due to normal force, L is the original length of the wire.

- **Bulk Modulus of elasticity (K or B) :** It is defined as the ratio of volume stress to the volumetric strain within the elastic limit. Thus,

$$K = \frac{\text{Volume stress}}{\text{Volumetric Strain}}$$

- Consider a spherical solid body of volume V and surface area a; when a force F is applied normally, the volume decreases by ΔV.
Volumetric strain = $-\Delta V/V$

$$\text{Normal stress} = \frac{F}{A} = p$$

$$K = \frac{\frac{F}{A}}{\frac{-\Delta V}{V}} = \frac{pV}{-\Delta V} \text{ or } \frac{1}{k} = \frac{1}{v}\left(\frac{\Delta V}{p}\right)$$

- **Modulus of Rigidity (η) :** It is defined as the ratio of tangential stress to the shearing strain within the elastic limit. Considering a solid metal cube whose lower face is fixed and its upper face is subject to a tangential force F. The body suffers a change in its shape but not in its volume. If q is angle through which the upper layer is sheared then,

$$\eta = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

$$\text{when Shearing stress} = \frac{F}{A}$$

$$\eta = \frac{DD^1}{DA} = \frac{L}{\Delta L} \text{ Tangential stress} = \frac{F}{A}$$

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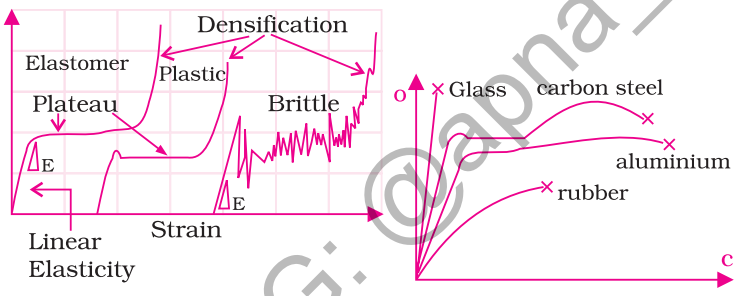
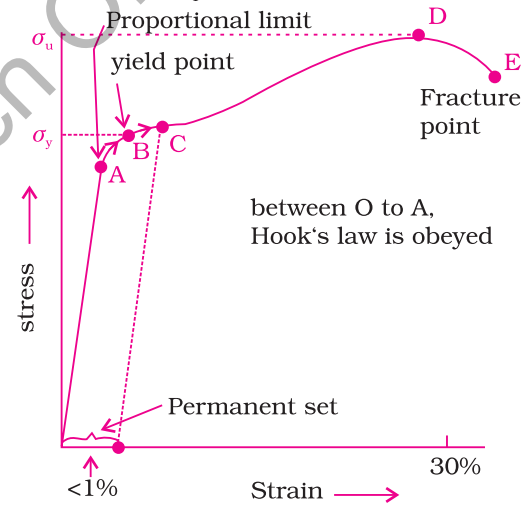
$$\eta = \frac{\text{Tangential stress}}{\text{Shearing strain}} = \frac{\frac{F}{A}}{\frac{-\Delta L}{L}} = \frac{F}{A} \times \frac{L}{\Delta L} = \frac{F}{eA}$$

- **Fracture and modulus of elasticity :** For isotropic materials, the presence of fractures affects the Young's and the shear moduli perpendicular to the planes of the cracks, which decrease (Young's modulus is faster than the shear modulus) as the fracture density increases, indicating that the presence of cracks makes bodies brittler.
- **Brittleness :** It is the property of a material to break into pieces when a stress is applied on it. It is opposite to ductility.
- A material based on elasticity can be classified elastic, hypoplastic, hyperelastic or plastic materials.

Elastic limit of materials :



- **Typical stress-strain curve for a ductile metal:** In the curve shown in the figure given below :
  AO = Elastic Range, P = Yield point
  OD = Breaking stress or tensile stress
  E = Breaking point, OO_1= Permanent set



Stress-strain curve for a metal

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- When the stress-strain relationship in a wire is studied, one finds that stress is directly proportional to the strain up to point A. Point 'A' is called the elastic limit and AO is called the elastic range. Hooke's law is valid till A. Beyond A, if the stress is removed, graph between stress and strain does not follow AO. BO' is followed when stress is zero, strain is not zero or a permanent deformation sets in the material. Therefore, OO' represents the permanent set.
- Here, beyond 'A', the stress - strain graph is a curve and that for a small stress, large strain is produced in the material. The material beyond A and up to 'P' is partly elastic and partly plastic in behaviour. Beyond 'P', the behaviour of the wire is very erratic. There is a large increase in the strain but a very small change in the stress.
- At this stage, the wire flows down upto the point C. The point 'P', when the wire yields to the applied stress and begins to flow, is called the yield point. The region PC is called the plastic region. Materials used for making sheets or wires must have a longer plastic region and must be ductile.
- Beyond C, the graph has a hump at D. Even if the wire is loaded by a little amount, the wire becomes thin at the weak portions of the wire and tends to break at E. The stress corresponding to the breaking point is called the breaking stress. Brittle substances generally have a small plastic region and the breaking stress lies closer to the elastic limit.
- **Poisson's ratio :** It is the ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching force, *i.e.* it can be defined as the ratio of the relative contraction strain (or transverse strain) normal to the applied load to the relative extension strain (or axial strain) in the direction of the applied load. It can be expressed as

$$\mu = -\varepsilon_t / \varepsilon_l$$

where μ = Poisson's ratio, ε_t = transverse strain and ε_l = longitudinal or axial strain

Strain can be expressed as

$$\varepsilon = \Delta l / L$$

where Δl = change in length (m) L = initial length (m)
- For most common materials the Poisson's ratio is in the range *0 – 0.5.*
- **Poisson's ratio is usually positive value :** Virtually, all common materials, such as the blue rubber band become narrower in cross section when they are stretched. The reason why they are in the continuum view is that most materials resist a change in volume as determined by the bulk modulus K (also called B) more than they resist a change in shape as determined by the shear modulus G.
- In the structural view, the reason for the usual positive Poisson's ratio is that inter-atomic bonds realign with deformation.

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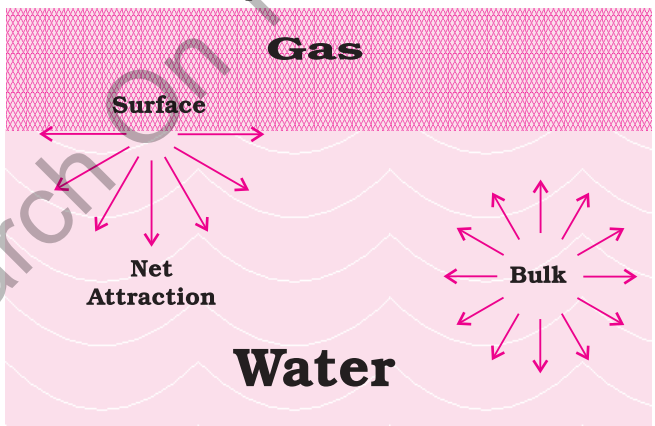
- **Poisson's ratio of materials :** Cork is an example of a material with a very low Poisson's ratio (nearly zero). When a cork is pushed into a wine bottle, it gets shorter but not thicker. (There is some axial strain, but barely any transverse strain.) Rubber, on the other hand, has a very high Poisson's ratio (nearly 0.5). When a rubber stopper is pushed into a chemical flask, the stopper gets shorter by some amount and wider by nearly half that amount. (The axial strain is accompanied by a large transverse strain). Corks can be pounded into bottles with a mallet. Pounding a rubber stopper into a glass flask with a mallet is likely to end in disaster.
- **Factors affecting elasticity :**

  Operations such as hammering, rolling, etc increase the elastic property of substances.

  Annealing that producies a uniform pattern of orientation of the constituent crystals, brings a decline in elastic property of material.

  Mostly an increase in temperature decreases the elastic property of materials except in case of invar steel where it remains unaffected.
- **Surface tension :** It is a phenomenon in which the surface of a liquid, where the liquid is in contact with gas, acts like a thin elastic sheet. The term is typically used only when the liquid surface is in contact with gas (such as the air). If the surface is between two liquids (such as water and oil), it is called "interface tension".
- **Causes of Surface Tension :** The different intermolecular forces, such as Van der Waals forces, draw the liquid particles together. Along the surface, the particles are pulled towards the rest of the liquid, as shown in the picture.



- Surface tension (denoted with the Greek variable, r) is defined as the ratio of the surface force F to the length d along which the force acts : $r = F / d$

Units of Surface Tension

- Surface tension is measured in SI units of N/m, although the more common unit is the CGS unit dyn/cm .
- Work done in forming a drop or bubble inside a liquid,

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$$W = T \times 4\pi r^2$$

where T is free surface energy density equal to W/dA.

- Work done in forming a bubble in air

$$w = T \times (2 \times 4\pi r^2) = 8\ \pi r^2 T$$

- Work done in spraying a liquid drop of radius R into equal droplets

$$w = T\ (4\pi R^2)\ (N^{1/3}-1)$$

Examples of Surface Tension :

- **Drops of water :** When using a water dropper, the water does not flow in a continuous stream, but rather in a series of drops. The spherical shape of the drops is caused by the surface tension of the water. However, the only reason the drop of water isn't completely spherical is because of the force of gravity pulling down on it. In the absence of gravity, the drop would minimize the surface area in order to minimize tension, which would result in a perfectly spherical shape.

  It's because of surface tension, most of the fruits we see are spherical or roughly spherical in shape. They intend to occupy the minimum surface area for the volume of matter, they contain.
- **Insects walking on water :** Several insects are able to walk on water, such as the water strider. Their legs are formed to distribute their weight, causing the surface of the liquid to become depressed, minimizing the potential energy to create a balance of forces so that the strider car move across the surface of the water without breaking through the surface.
- This is similar in concept to wearing snow shoes to walk across deep snowdrifts without the sinking of feet.
- **Needle (or paper clip) floating on water :** Although the density of these objects are greater than water yet the surface tension along the depression is enough to counter act the force of gravity pulling down on the metal object.

  Floating of eggs in water is also because of surface tension.
- **Soap Bubble :** When we blow a soap bubble, we create a pressurized bubble of air which is contained within a thin, elastic surface of liquid. Most liquids cannot maintain a stable surface tension to create a bubble; that is why soap is generally used in the process, it stabilizes the surface tension through something called the Marangoni effect.
- When the bubble is blown, the surface film tends to contract.

  This causes the pressure inside the bubble to increase. The size of the bubble stabilizes at a size where the gas inside the bubble won't contract any further, at least without popping the bubble.
- In fact, there are two liquid-gas interfaces on a soap bubble the one on the inside of the bubble and the one on the outside of the bubble.

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- **Pressure inside a Soap Bubble :** To consider the pressure inside the soap bubble of radius R , ignoring the very slight difference in inner and outer radius, the circumference is $2\pi R$.
- Each inner and outer surface will have a pressure of r along the entire length, so that total force from the surface tension (from both the inner and outer film) is, therefore, $2r = (2\pi R)$.
- Inside the bubble, however, there is a pressure p that acts over the entire cross-section πR^2, resulting in a total force of $\pi(\pi R^2)$.
- Since the bubble is stable, the sum of these forces must be zero , therefore:

  $2 r (2\pi R) = p(p\pi R^2)$

  Or $p = 4 r / R$
- The *difference* between the interior pressure p and the exterior pressure P_{net} : $p - p_e = 4 r / R$
- **Pressure in a liquid Drop :** Analyzing a drop of liquid, as opposed to a soap bubble, is simpler. Instead of two surfaces, there is only the exterior surface to consider, so a factor of 2 drops out of the earlier equation (remember where we doubled the surface tension to account for two surfaces) to yield : $p - p_e = 2 r / R$

Experimental Surface Tension Values

Liquid in contact with air	Temperature (degrees C)	Surface Tension (N/m, or dyn/cm)
Benzene	20	28.9
Carbon tetrachloride	20	26.8
Ethanol	20	22.3
Glycerin	20	63.1
Mercury	20	465.0
Olive oil	20	32.0
Soap solution	20	25.0
Water	0	75.6
Water	20	72.8
Water	60	66.2
Water	100	58.9

- **Capillarity :** It also called capillary action, is the ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity. The effect can be seen in the drawing up of liquids between the hair of a paint brush, in a thin tube, in porous materials such as paper, in some non-porous materials such as liquefied carbon fibre, and in a cell. It occurs because of intermolecular attractive forces between the liquid and solid surrounding surfaces. If the diameter of the tube is sufficiently small then the combination of surface tension (which is caused by cohesion within the liquid) and adhesive forces between the liquid and the container act to lift the liquid.

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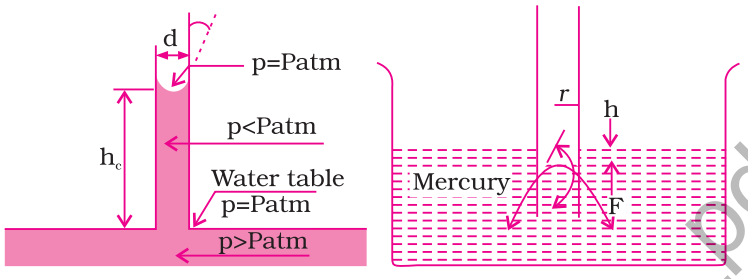
- With some pairs of materials, such as mercury and glass, the intermolecular forces within the liquid exceed those between the solid and the liquid, so a convex meniscus is formed, and capillary action works in reverse.



- Angle of contact θ and shape of meniscus :
  - If θ > 90°, the meniscus is convex, *h* will be negative, *i.e.*, the liquid will descend in capillary tube like mercury in a glass capillary.
  - If θ = 90°, the meniscus is plane, hence no phenomenon of capillarity.
  - If < 90°, the meniscus is concave towards air, h will be positive, *i.e.* the level will rise in capillarity.

  Examples of capillary

  (i) Blotting paper sucks ink due to the small holes (pores) of the paper which act like the capillary.

  (ii) Through the wicks of K-oil, the oil rises into the wick due to capillary action.

  (iii) In the branches of plants and leaves, the water and nutritional salts are transported through the capillary action.

  (iv) In the artificial satellites (in their state of weightlessness) if a capillary tube is dipped into water then the water will rise upto its full height.

  (v) Just after rainfall, farmers plough the field to open up the capillaries for downward movement of water.

- **Viscosity :** It also known as dynamic viscosity, absolute viscosity, or simply viscosity. It is represented by the Greek letter ç (eta). It is defined informally as the quantity that describes a fluid's resistance of a fluid to flow. Mathematically, it is the ratio of the shearing stress to the velocity gradient in a fluid.

$$\eta = \frac{F/A}{\Delta v_x/\Delta z} \text{ or } \eta = \frac{F/A}{dv_x/d_z}$$

often expressed using Newton's equation for fluids (which is similar to Newton's second law of motion).

$$\frac{F}{A} = \eta\frac{\Delta v_x}{\Delta_z} \text{ or } \frac{F}{A} = \eta\frac{dv_x}{d_z}$$

- The SI unit of viscosity is the pascal second [Pa. s]. The Gaussian unit of viscosity is the poise [P = dyne s/cm^2]. Ten poise equals to one pascal second [10 P = 1 Pa. s].

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- **Kinematic viscosity :** It is represented by the Greek letter $\upsilon = \frac{\eta}{\rho}$ and is defined informally as a measure of the resistive flow of a fluid under the influence of gravity. Mathematically it, is considered as the ratio of the viscosity of a fluid to its density.

$$\upsilon = \frac{\eta}{\rho}$$

- The SI unit of kinematic viscosity is the square metre per second [m^2/s].The Gaussian unit of kinematic viscosity is the stokes [St = cm^2/s]. Ten thousand stokes equals to one square metre per second [10,000 stoke = 1 m^2/s].
- **Stoke's law and terminal velocity :** It states that if a sphere of radius r moves with velocity υ through a fluid of viscosity of, the viscous force opposing the motion of sphere is

$$F = 6\pi\eta r v$$

and the terminal velocity of sphere failing in a fluid of density σ and coefficient of viscosity η is $V_T = \frac{2}{q} r^2 \left[\frac{\rho - \sigma}{\eta}\right] g$

- **Factors Affecting Viscosity :** Viscosity is the property of materials; therefore, varies with type of material.

The viscosity of simple liquids

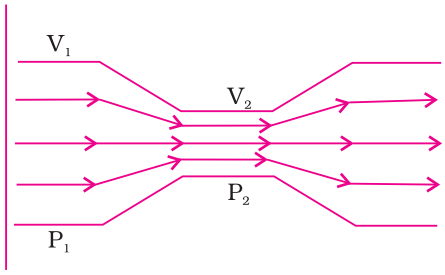
- decreases with increasing temperature
- increases under very high pressures.

The viscosity of gases

- increases with increasing temperature
- is independent of pressure and density

- **Bernoulli's principle :** It states, "For a perfectly incompressible liquid, flowing in a continuous stream, the total energy of a particle remains the same, while the particle moves from one point to another." This statement is based on the assumption that there are no losses due to friction in the pipe. Mathematically,

$$\frac{p}{\rho g} + \frac{\upsilon^2}{2g} + Z = \text{Constant}$$



where, z = Potential Energy, $v^2/2g$ = Kinetic Energy and $P/\rho g$ = Pressure Energy

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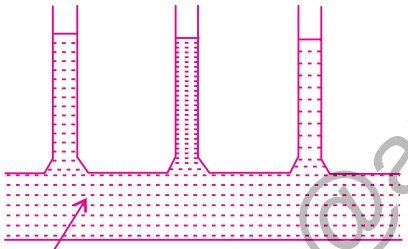
- If a fluid is flowing through a horizontal pipe of varying cross-sectional area for example as in given in figure, the fluid speeds up in constricted areas so that the pressure 'on' the fluid exerts is the where the cross section is the smallest. This phenomenon is also called the Venturi effect. The Venturi effect has several applications including that associated with generating lift atop an aerofoil, making all forms of flight on aeroplanes gyroplanes, and helicopters possible.
- The Bernoulli's theorem is also representative the law of the conservation of energy, *i.e.* the sum of all energy in a steady, streamlined, incompressible flow of fluid is always a constant.

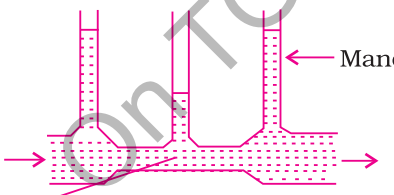
Effects of Bernoulli's principle:

1. Liquid passing through tube



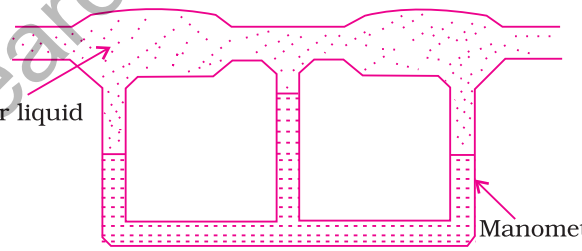
Constant pressure drop in uniform tube

2.



Extra pressure drop in narrower part

3. Restricted tube



Applications of Bernoulli's theorem :

- **Atomizer or sprayer :** The common form of atomizer is shown in the figure below. When the rubber bulb is squeezed, the air blows in the tube T with high speed. According to Bernoulli's theorem a low pressure P_2 is created inside T that is much less than

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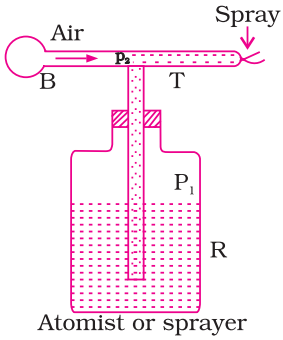
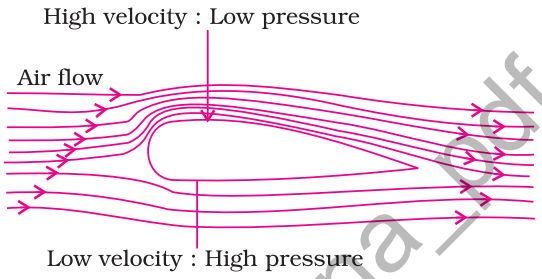
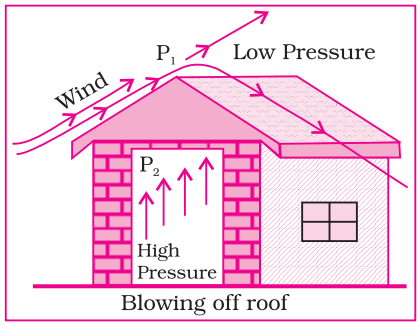
atmospheric pressure P_1 on the liquid surface in the vessel R. Due to this pressure difference, the liquid rises up in the tube T and is pushed out with air through nozzle N in the form of a spray. This principle is used in a paint sprayer, oil scent and nasal sprayer.



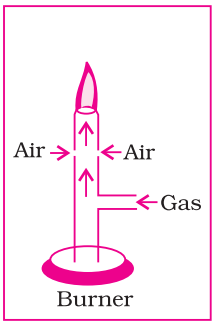
Atomist or sprayer



- **Lift on an aeroplane wing :** The shape of the aeroplane wing is peculiar. Its upper surface is more curved than its lower surface and its leading edge is thicker than its trailing edge. As an airplane moves forward, the air blown in the form of stream lines over the wings of the airplane as shown in the figure. As the upper surface of the wing is more curved than its lower surface, the speed of air above the wings is larger than the speed of the air below the wings. According to Bernoulli's theorem, the pressure above the wings becomes less than that the pressure below the wings. Due to this difference of pressure on the two sides of the wings upper and lower a vertical lift acts on the airplane. When this lift is sufficient to overcome the gravity pull on the airplane, the airplane is lifted up.
- **Blowing off the roofs during storms :** In a storm, sometimes the light roofs of thatched houses are blown off. This is because a high velocity wind blowing over the roofs decreases the pressure above the roof and, therefore, the greater atmospheric pressure below the roof lifts it up.



Blowing off roof



Burner

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- **Bunsen's Burner :** In Bunsen's burner, the gas escapes through the fine nozzle with a high velocity. It results in the lowering of pressure in the neighbourhood of the nozzle. Due to decrease in pressure inside the burner, the atmospheric air enters through holes. The air and the gas mixture rising up produce a flame, when ignited.
- **A person standing near the railway track** is pulled towards the train. When a fast moving train passes close to a person it decreases the pressure between the person and the train. Due to the greater pressure on the other side of the person, the person gets pushed towards the railway track.
- **Two ships** sailing in the ocean get pulled towards each other, if they come closer to each other.
- **Vacuum Brakes :** Vacuum brakes are used for stoping the train in case of emergency.

  In order to stop the train, the steam pressure decreases and the piston of the brakes gets lifted, which through a mechanical system lifts the brakes to stop the train.
- **Curved motion of spinning balls** is also based on the principle of Bernoulli's theorem. (Magnus effect)
- **Sol-gel processing :** The sol-gel process refers to room temperature 'solution routes' for preparing mainly oxi dematerials. The process involves the hydrolysis and polymerization of metal alkoxide pre cursors of silica, zirconia, etc. The solutions of the precursors are reacted to form irreversible gels that dry and shrink to rigid oxide forms.

  Use : (Environmentally acceptable precursors)

  ↓

  Assemble to size approximating device :

  ↓ (Chemical and physical transformation)

  Model co-operative properties.

  The concept of sol-gel processing is unique for the processing of the nano structures. It starts with a nanometer sized molecular unit and goes through the reaction (Changes) that are. also on the nanometer scale .

□□□

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Chapter 12

HEAT AND THERMODYNAMICS

Laws of thermodynamics, classes of thermodynamic system, types of thermodynamic processes, thermodynamic potentials, specific heat capacity, molar heat capacity, basic mechanisms of heat transfer, thermometers and their types.

- **Thermodynamics** is the field of physics that deals with the relationship between heat and other properties (such as pressure, density, temperature, etc.) in a substance.
- Specifically, thermodynamics focuses largely on how the heat transfer is related to various energy changes within a physical system undergoing a thermodynamic process. Such processes usually result in work being done by the system and are guided by the laws of thermodynamics.
- **Laws of thermodynamics :** Thermodynamics is principally based on a set of four laws which are universally valid when applied to systems that fall within the constraints implied by each.
- **Zeroth law of thermodynamics :** It states, "If two systems are each in thermal equilibrium with a third, they are also in thermal equilibrium with one another. It implies that thermal equilibrium is an equivalence relation in the set of thermodynamic systems under consideration. Systems are said to be in equilibrium if the small, random exchanges between them (e.g. Brownian motion) do not lead to a net change in energy.
- First law provides an empirical definition of temperature and justification for the construction of practical thermometers.
- **First law of thermodynamics:** It states that the internal energy of an isolated system is constant.
- This first law is an expression of the principle of the conservation of energy which is usually formulated by assuming that the change in the internal energy of a closed thermodynamic system is equal to the difference between the heat supplied to the system and the amount of work done by the system on its surroundings. It is important to note that internal energy is a state of the system whereas heat and work modify the state of the system. In other words, a specific internal energy of a system may be achieved by any combination of heat and work; the manner by which a system achieves a specific internal energy is path-independent.
- **Second law of thermodynamics :** It states that heat cannot spontaneously flow from a colder location to a hotter location. It being more an expression of the universal principle of decay observable in nature explains the phenomenon of irreversibility in nature.

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- **Third law of thermodynamics :** It states that as a system approaches absolute zero, all processes cease and the entropy of the system approaches a minimum value. Third law provides an absolute reference point for the determination of entropy. The entropy determined relative to this point is the absolute entropy. "The entropy of all systems and of all states of a system is the smallest at absolute zero," or equivalently however it is impossible to reach the absolute zero of temperature by any finite number of processes.
- Absolute zero refers to the temperature at which all activity would stop if it were possible to happen. It is –273.16 °C (degrees Celsius), or –459.67 °F (degrees Fahrenheit) or 0K (kelvin).
- **Classes of thermodynamic systems :** A thermodynamic system can be classified and distinguished into three classes of systems as listed in the table given below :

Interactions of thermodynamic systems

Type of system	Mass flow	Work	HEAT
Open	Yes	Yes	Yes
Closed	No	Yes	Yes
Thermally isolated	No	Yes	No
Mechanically isolated	No	No	Yes
Isolated	No	No	No

- As time passes in an isolated system, internal differences in the system tend to even out and pressures and temperatures tend to equalize, as do density differences. A system in which all equalizing properties and processes have gone to completion is considered to be in a state of thermodynamic equilibrium.
- The thermodynamic processes which develop so slowly as to allow each intermediate step to be at an equilibrium state are said to be reversible processes.

Types of thermodynamic processes

	Types	Characteristics
1.	Isobaric process	Occurs at constant pressure.
2.	Isochoric process	Occurs at constant volume (also called Isometric or Isovolumetric).
3.	Isothermal process	Occurs at a constant temperature.
4.	Adiabatic process	Occurs without the loss or gain of energy by heat.
5.	Isentropic process	Reversible adiabatic process that occurs at a constant entropy.
6.	Isenthalpic process	Constant enthalpy.
7.	Steady state process	Occurs without a change in the internal energy.

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- **Thermodynamic potentials :** These are different quantitative measures of the stored energy in a system. Potentials are used for measuring energy changes in systems as they evolve from an initial state to a final state. The potential used depends on the constraints of the system, such as constant temperature or pressure. The five most well known potentials are:

Name	Symbol	Formula	Natural variables
Internal energy	U	$f(TdS-pdV_i+\Sigma_i \mu_i dN_i)$	S,V, $\{N_i\}$
Helmholtz free energy	F	U-TS	T,V, $\{N_i\}$
Enthalpy	H	U + pV	S,p, $\{N_i\}$
Gibbs free energy	G	U + pV – TS	T,p, $\{N_i\}$
Landau Potential (Grand potential)	Ω, ϕ_g	$U-TS-\Sigma_i \mu_i n_i$	T,V, $\{\mu_i\}$

where T is the temperature, S the entropy, p the pressure, V the volume, μ the chemical potential, N_i the number of particles in the system, and i is the count of particle types in the system.

- Thermodynamic potentials can be derived from the energy balance equation applied to a thermodynamic system.
- **Heat capacity :** It refers to energy required to change the temperature of a given substance assuming that no phase changes are occurring. There are two main ways that heat capacity is reported.
- **Specific heat capacity or specific heat :** It is represented by the symbol C. It refers to the amount of heat energy or any other way possible that is required to increase the temperature of *one gram* of a substance by 1^0C or 1K. Specific heat capacity usually has units of J/gram.K.
- **Molar heat capacity :** It represented by symbol C_m or C mol, measures the amount of thermal energy required to raise the temperature of one mole of a substance by 1^0C or 1K. It has unit of J/mol. K.
- To calculate the heat released or absorbed using the specific heat capacity c, the mass of the substance m, and the change in temperature ΔT are considered in the following equation:

$$q = m \times c \times \Delta T$$

- **Basic Concepts of Heat Transfer :** The heat of a material is understood as a representation of the energy contained within the particles of that material. This is known as the kinetic theory of gases, though the concept also applies in varying degrees to solids and liquids as well. The heat from the motion of these particles can transfer into nearby particles, and therefore into other parts of the material or other materials, through a variety of means:

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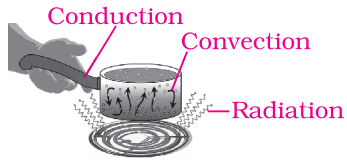
- **Thermal Contact** is when two substances affect each other's temperature.
- **Thermal Equilibrium** is when two substances in thermal contact no longer transfer heat.
- **Thermal Expansion** takes place when a substance expands in volume as it gains heat. The reverse thermal contraction also exists.
- **Conduction** is when heat flows through a heated solid from the region at high temperature to the region at low temperature.
- **Convection** is when heated particles transfer heat to another substance, such as cooking something in boiling water. It is of common occurrence in fluids, *i.e.* liquids and gases.



- **Radiation** is when heat is transferred through electromagnetic waves, such as from the sun or a heated material such as an electric room heater.
- **Insulation** is when a low-conducting material is used for preventing heat transfer.

Problem : Find the final temperature of the mixture, if two cups of water having masses m_1=150g and m_2 = 250g and temperatures T_1= 30°C and T_2 = 75 °C are mixed in an isolated system in which there no heat losts is feasible. (C_{water}=1cal/g.°C)

Solution: $Q_{gained} = Q_{lost}$

$m_1c_1\Delta T_1 = m_2c_2\Delta T_2$

$150g.\ 1.\ (T_f - 30^0C) = 250g.1.\ (75^0C - T_f)$

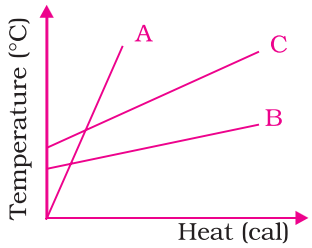
$3T_f - 90^0C = 375^0C - 5T_f$

$8T_f = 465^0C$

$T_f = 465°\ C/8 = 58.1°C$

The final temperature of the mixture is 58.1^0C.

Problem : The graph given below shows the relation between given heat and change in the temperatures of the three matters A, B and C having the same masses. Compare the specific heat capacities of these matters.



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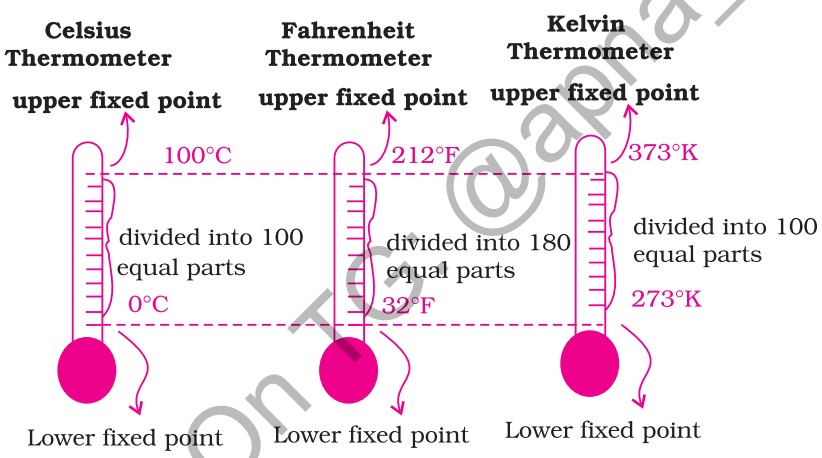
Solution : $Q = m.c. (T_f - T_i)$

Or $1/m.c = (T_f - T_i)/Q$

Slope of graph gives the inverse of heat capacity. Since, the masses of these matters are equal, B has the greatest specific heat capacity because, with the same amount of heat, change in the temperature of the B is lower than the other two matters. Moreover, A has the minimum specific heat capacity, because the change in its temperature with the same amount of heat is larger than that of the other. Two finally, specific heat capacity of the C is between A and B. Thus the correct order is : B > C > A.

- **Thermometer :** It is a device we use to measure temperature of matters. There are three types of thermometer.



- In the Celsius thermometer, lower fixed point is 0°C and upper fixed point is 100°C, in the Fahrenheit thermometer lower fixed point is determined as 32°F and upper fixed point as 212°F and finally, the lower fixed point of the Kelvin thermometer is 273K and upper fixed point is 373K. These temperatures are determined considering the freezing point and boiling point of water.
- We can convert the measurements of Celsius to Kelvin or Fahrenheit to Kelvin, by using the following equation :

$$\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$$

Problem : Find the values of 40°C in Fahrenheit and Kelvin thermometers.

Solution : Using the above equation

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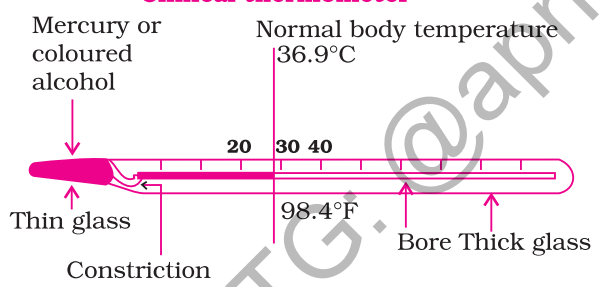
$$\frac{C}{100} = \frac{F-32}{180} \quad \frac{C}{100} = \frac{K-273}{1}$$

$$\frac{40°C}{100} = \frac{F-32}{180} \quad \frac{40°C}{100} = \frac{K-273}{180}$$

$$F = 140°F \quad K = 313\ K$$

- **Clinical thermometer :** It is a thermometer used for measuring body temperature. Most old thermometers use mercury. It is accurate and sensitive, because it has a narrow cappillary where the liquid rises very fast. It is used in clinics by doctors, so called as doctor's thermometer also. Most of these thermometers show both the scales, Celsius scale and Fahrenheit scale and scale runs from 35 degrees Celsius to 42 degrees Celsius. Clinical thermometer scale is characterized by the presence of a constriction close to bulb to prevent any change in temperature once removed from the body.

Clinical thermometer



- **Thermoelectric thermometers :** They use thermo e.m.f. as thermo metric quantity in measuring the temperature of range –200°C to 1600°C using the relation: $e = at + bt^2$
- **Platinum Resistance thermometer :** It use resistance thermometric quantity. In measuring the temperature of range –200°C using the formula :

$$t_c = \frac{R_1 - R_0}{R_{100} - R_0} \times 100°C$$

- **Phase transition of water :** The graph given shows the phase transition of water. The ice initially gains heat in the interval between points A and B. When at B , its temperature becomes 0^0C. In the interval B and C no change in the temperautre occurs as the heat absorbed is used for breaking the bonds of molecules. The 2nd region includes both water and ice. After melting process is completed, in the 3rd region there is only water and temperature of water starts to increase. When the temperature of the water becomes 100 °C, it starts to boil and the evaporation of it speeds up. In the 4th region, our mass exists in two states, water and steam. After the completion of evaporation, all water is converted into the steam and in region 5, we have only vapour of water.

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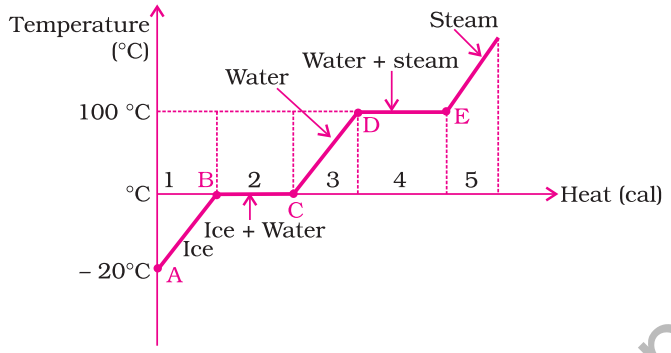
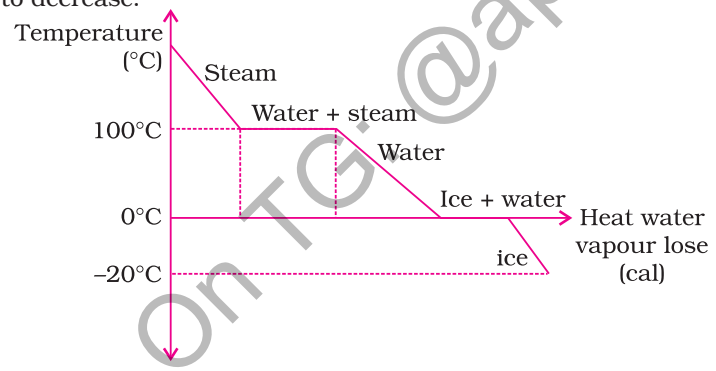


➢ The graph given below shows the relation of temperature v/s loss of heat by water vapour. The graph shows the condensation of water vapour as heat is lost and temperature decreases at 100 °C. At this temperature it condensates and becomes water; after heat is lost until it reaches the temperature 0°C and starts to freeze. Finally, if it continues to lose heat, the temperature also continues to decrease.



➢ **Heat-induced expansion :** Heat-induced expansion has to be taken into account in most areas of engineering. A few examples are :

- ❖ Metal-framed windows need rubber spacers.
- ❖ A space needs to be left in rails to provide space for expansion.
- ❖ Metal hot water heating pipes should not be used in long straight lengths.
- ❖ Large structures such as railways and bridges need expansion joints in the structures to avoid sun kink.
- ❖ A grid iron pendulum uses an arrangement of different metals to maintain a more temperature stable pendulum length.
- ❖ A power line on a hot day is droopy, but on a cold day it is tight. This is because metals expand under heat.
- ❖ Expansion joints absorb the thermal expansion in a piping system.
- ❖ Precision engineering nearly always requires the engineer to pay attention to the thermal expansion of the product. For example, while using a scanning electron microscope even small changes

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in temperature such as 1 degree can cause a sample to change its position relative to the focal point.

- **Expansion in matter :** For many solids, expansion is directly proportional to temperature change.
  Areas expand twice as much as lengths do. $\Delta A = 2\alpha A_o \Delta T$
  Volumes expand three times as much as lengths do.
  $$\Delta V = 3\alpha V_0 \Delta T$$
  Anisotropic expansion : Some materials expand differently in different directions, notably graphite and wood (lumber or timber).
- Very low temperatures are measured using vapour pressure thermometers while very high temperatures are measured using pyrometers
- **Liquids :** Liquids can only expand in volume.
  $$\Delta V = \beta V_0 \Delta T$$
  Liquids have higher expansivities than solids.
  $$\beta \sim 10^3/K,\ 3\alpha \sim 10^5/K$$
- **Applications :** Liquid in glass thermometer. The alcohol used is coloured red to look like red wine.
  Alcohol thermometer is preferred to the mercury thermometer because of its large value of the coefficient of cubic expansion.
  ethyl alcohol $1120 \times 10^6/K$
  mercury $181 \times 10^6/K$
  glass $3(8.5 \times 10^6/K) = 25.5 \times 10^6/K$
- **Water :** It has anomalous expansion, ice being less dense than water. It is most dense at 4°C ($\rho = 999.973\ kg/m^3$).
- The expansion of water causes the bursting of frozen pipes and turn over of lake water in spring.
- **Plutonium :** It undergoes more phase transitions at ordinary pressures than any other element. As plutonium is heated it transforms through six different crystal structures before melting — α [alpha], β [beta], γ [gamma], Δ [delta], δ [delta prime] and ε [epsilon]. Physical properties like density and thermal expansion vary significantly from phase to phase making it one of the more difficult metal to machine and work.
- **Carnot Cycle :** The Carnot cycle is the most efficient cycle possible. It consists of four basic reversible processes meaning that the cycle as a whole is also reversible.
- For an ideal gas Carnot cycle, the four steps are shown below:
  - Isothermal expansion from V_a, P_a to V_b, P_b at T_{hot} absorbing heat Q_h.
  - Reversible adiabatic expansion from V_b, P_b to V_c, P_c as the temperature falls from T_{hot} to T_{cold}.
  - Isothermal contraction from V_c, P_c to V_d, P_d at T_{cold} exhausting heat Q_c.
  - Reversible adiabatic contraction from V_d, P_d to V_a, P_a as the temperature rises from T_{cold} to T_{hot}.

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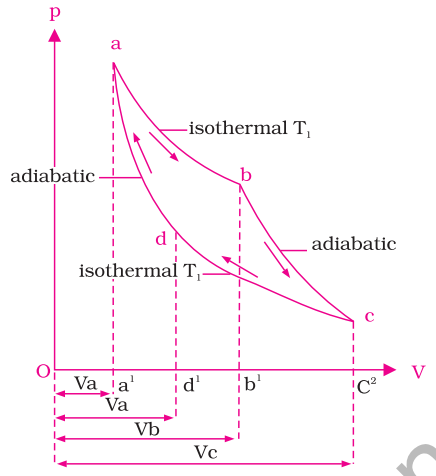

- **Carnot's Principle :** An irreversible heat engine operating between two heat reservoirs at constant temperatures cannot have an efficiency greater than that of a reversible heat engine operating between the same two temperatures.
- Carnot's principle is also an another form of second law of thermodynamics as it states that "It is not possible to make a heat engine whose only effect is to absorb heat from a high-temperature region and turn all that heat into work". That is, it is not possible to design a heat engine that does not exhaust heat to the environment. Or, it is not possible to design a heat engine that has an efficiency of 1.00 or 100%.
- **Carnot's Theorem :** During one part of the cycle performed in an engine, some heat is absorbed from a hot reservoir. During another part, a smaller amount of heat is rejected to a cooler reservoir. The engine is therefore said to operate between these two reservoirs. The processes that make up this cycle are either isothermal or adiabatic as mentioned above.
- The system returns to its initial state after an amount of work, *W*, has been done to the system. By the conservation of energy,

$$W = Q_h - Q_c$$

- The thermal efficiency, *n*, of a cycle operating as a heat engine is defined as

$$\eta = \frac{W}{Q_h}$$

- The absolute value sign has been used for eliminating any confusion about which way the heat is flowing and whether Q is positive or negative. We can use conservation of the energy in the form of first equation to find the efficiency of the cycle in terms of Q_c and

$$\eta = 1 - \frac{|Q_c|}{|Q_h|}$$

- The above two equations apply to any cycle. The Carnot cycle is useful in studying real engines and refrigerators largely because one can derive the efficiency of the ideal gas Carnot cycle in terms of the temperatures of the heat reservoirs.

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Chapter 13

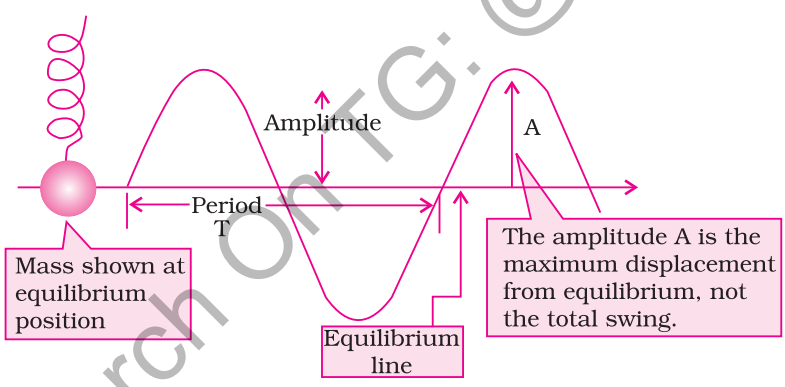
SIMPLE HARMONIC MOTION

Simple harmonic motion, time period, frequency, wavelength, SHM as circular motion, spring mass system, simple pendulum, oscillations in SHM.

- **Simple harmonic motion :** When something oscillates, it moves back and forth with time. It is helpful to trace out the position of an oscillating particle with time.

Time period, Frequency and Amplitude :

- The time taken for the particle to complete one oscillation, that is, the time taken for the particle to move from its starting position and return to its original position is known as the *time period* and is generally given the symbol *T*. The frequency *f* is related to the period, it is defined as how many oscillations occur in one second. Since the period is the time taken for one oscillation, the frequency is given by $f = 1/T$



- The frequency is measured in [s^{-1}]. This unit is known as the Hertz (Hz) in honour of the physicist Heinrich Hertz. The maximum displacement of the particle in metre from its resting position is known as the *amplitude*. The frequency is also given the symbol *f*.
- **Simple Harmonic Motion:** It's the motion in which the acceleration causing the motion *a* of the particle or object is proportional and in opposition to its displacement *x* from its equilibrium position, *i.e.*

$$a(t) = \alpha\text{-}x(t)$$

- If *k* is a constant of proportionality then acceleration being the second derivative of position, leads to the differential equation:

$$x''(t) = -k\,x(t)$$

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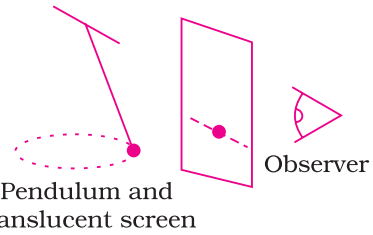
- **SHM and circular motion:** SHM (Simple Harmonic Motion) is closely related to circular motion as shown below, if one takes an object that moves in a circular path, like a ball stuck on a turntable. When only on the y-component of the motion, the path is considered with time, it traces out as a wave. $y(t) = A \sin(\omega t)$



- The period of the motion is equal to the time it takes for one rotation. Therefore, if we know the angular velocity $\omega = \theta/t$, for one rotation, $\omega = 2\pi/T$. Therefore, the time period is also equal to

$$T = 2\pi/\omega$$

- The particle can also be at different speeds if connected with the period. The frequency is the number of oscillations per second.
- Consider the particle undergoing simple harmonic motion . The displacement with time takes the form of a sinusoidial wave. The velocity of the particle can be calculated by differentiating the displacement. The result is also a wave but the maximum amplitude is delayed so that when the displacement is at a maximum, the velocity is at its minimum and when the displacement is zero the velocity has its greatest value.

  SHM is characterized by the acceleration, a being oppositely proportional to the displacement, y.
- **SHM, time period and maximum acceleration:** The time for the maximum velocity and acceleration can be determined using the equation;

$$a(t) = -\omega^2 y(t)$$

- The maximum magnitude of the velocity occurs when $\sin(\omega t - \varphi)$ is 1 or -1. Therefore, the maximum velocity is $\pm \omega A$. The minus sign indicates that the direction of travel is in the opposite direction.
- The maximum acceleration occurs where the argument of cosine is $a = y''(t) = -\omega^2 A \cos(\omega t - \varphi)$ is -1 or 1.

  Thus, the maximum acceleration is $\pm \omega^2 A$ that occurs at the ends of the oscillations, where the direction changes.
- **Spring mass system :** Consider a spring of spring constant k connected to a mass m. If the mass is displaced from its equilibrium

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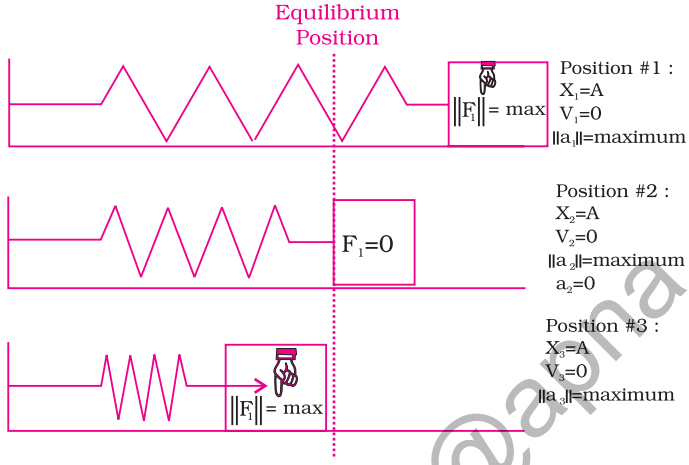
position by a distance x, a force F will act in the opposite direction to the displacement.

Following Hooke's Law, the magnitude of the force is given by

$$F = -kx$$



- When the mass is released, the force acts on the mass to bring it back to its equilibrium position. However, if there is no friction, the inertia of the mass will cause it to overshoot the equilibrium position and the force will act in the opposite direction slowing it down and pulling it back. The action of this force on the mass keeps it oscillating backwards and forwards.
- The spring mass system consists of a spring with a spring constant of k attached to a mass, m. The mass is displaced by a distance x from its equilibrium position; work is done and potential energy is stored in the spring. If the mass is displaced by a small distance dx, the work done in stretching the spring is given by $dW = F\,dx$.
- The force on the spring is assumed to obey Hooke's law. Therefore, the restoring force is proportional to the extension. The work done is then $dW = -kx\,dx$
- The total work

$$W = \int kx\,dx = -1/2\ kx^2 + C$$

- At the time of release, the energy of the system will consist totally of potential energy.

  $PE = -1/2\ kx^2$ and the potential energy as a function of time is

$$PE(t) = 1/2k\,A\cos^2(\omega t - \varphi)$$

- As the spring pulls the mass towards the equilibrium position, the potential energy is transformed into kinetic energy until at the equilibrium position the kinetic energy will be maximised. The KE is $1/2\ mv^2$ and the maximum velocity occurs at x=0, the velocity will be ω A. Kinetic energy = $KE = \frac{1}{2} m\omega^2 A^2 \sin^2(\omega t - \omega\varphi)$

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- From the conservation of mechanical energy, the sum of energy between kinetic energy and potential energy will always be the same.

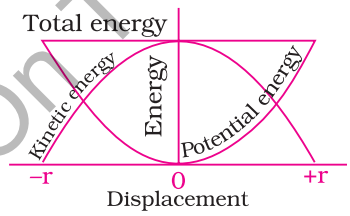
  $U = KE(t) + PE(t) = 1/2\ m\omega^2A^2 \sin^2(\omega t - \varphi) + 1/2k\ A \cos^2(\omega t - \varphi)$

  $1/2m\omega^2x^2 = 1/2k\ x^2$ is transferred into kinetic energy by moving the mass. For a particle undergoing simple harmonic motion, the displacement x is given by relation $F = -k\ x$. The potential energy is gradually transferred to kinetic energy. Kinetic energy is given by $1/2\ mv^2$. Summing up the kinetic energy and potential energy, the total energy

  $$U=(1/2)A^2(\ k + m) = 1/2\ k\ A^2$$

  $$\text{Since } k = m\omega^2 \text{ and } \cos^2 x + \sin^2 x = 1$$

- There is change in energy betweeen kinetic energy and potential energy with time. The potential energy is the highest at the positions of maximum displacement.
- The kinetic energy is maximum when the velocity is the greatest, *i.e.* as it passes the equilibrium position.
- The total mechanical energy of the system, is the sum of the potential energy and kinetic energy. The total energy remains constant if there are no losses to friction, heat or air resistance.



- **Simple pendulum :** It has at one end, massless string with suspended mass *m* and the other end fixed to a stationary point. If the mass is displaced by a small distance, the angle moved is small.
- The torque on the fixed point P is

  $\uparrow\ = I\alpha - mg \sin \alpha(t)$

  $\Rightarrow mL^2 \frac{d^2\theta}{dt} = -mgL \sin\theta$

  $\rightarrow \frac{d^2\theta}{dt} = -\frac{g}{L}\sin\theta$

  $= 0$

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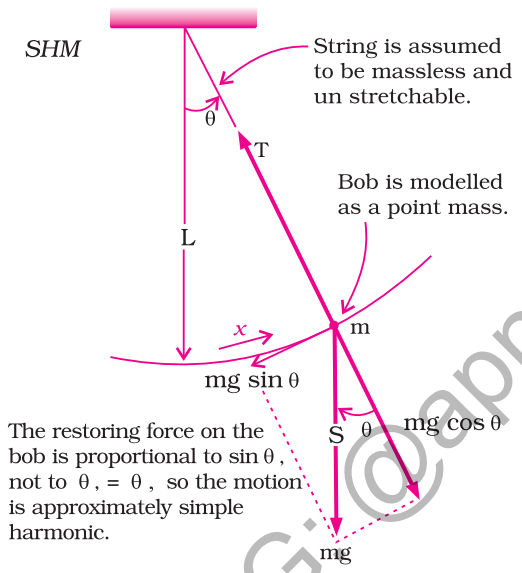
- This has the same form as simple harmonic motion equation, x"(t) - ω^2x(t), and so the solution is $\theta(t) = \theta_0 \cos(\omega t - 2\pi)$, the angular frequency is $\omega = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ and time period $T = 2\pi(l/g)^{1/2}$



- It is interesting to note that the mass does not appear in this equation. This means that the frequency of the period depends only on the length of the string and the force of gravity, not on the mass of the bob $T = 2\pi\sqrt{\frac{l}{g}}$.
  - Pendulum with shorter strings will oscillate faster than the pendulum with a longer string.
  - A pendulum on the moon, where the force of gravity is 1/6th that of the gravity on the earth, will also take longer to oscillate.
  - In an elevator, accelerating upwardly, the time period decreases; while when accelerating downward, the time period increases.
  - A simple pendulum will show an increase in its time when accelerating horizontally than when at rest such as in a moving train.
- **Oscillation as simple harmonic motion :** An oscillation follows simple harmonic motion if it fulfils the following two rules:
  - Acceleration is always in the opposite direction to the displacement from the equilibrium position.
  - Acceleration is proportional to the displacement from the equilibrium position.

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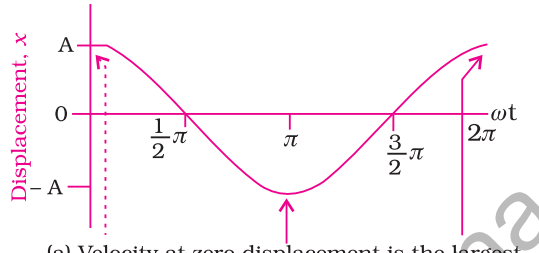
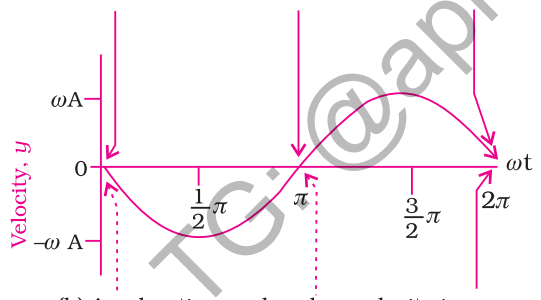
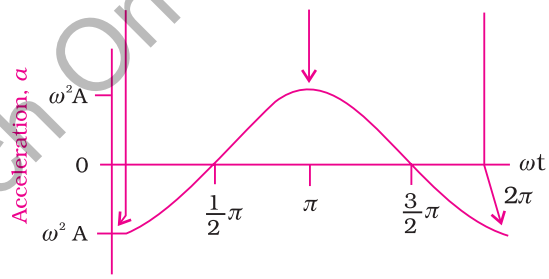
- Acceleration and displacement are linked by the following equation: $a(t) = -\omega^2 x(t)$; ω is the *angular frequency* of oscillation, and is given by $2\pi / T$ or $2\pi f$.
- T is the period of oscillation (s), $f=1/T$ = frequency of oscillation (Hz) and x is the displacement (m).Using Newton's 2nd Law , $F=ma$ Force on the object due to inertia will be : $F= -m\omega^2 x$



(a) Velocity at zero displacement is the largest



(b) Acceleration peaks when velocity is zero



(C) Acceleration peaks when velocity is zero

- Using Hooke's Law of springs $F = -kx$, force on the oscillating mass due to the springs is $F = -kx$. These two forces are always in balance, so

$$m\omega^2 x - kx = 0$$

- Hence, the resonant frequency:

$\omega^2=(kx) / (mx) = k/m$, $\omega = (k/m)^{1/2}$ $f = 1/ 2\pi x [(k/m)^{1/2}]$

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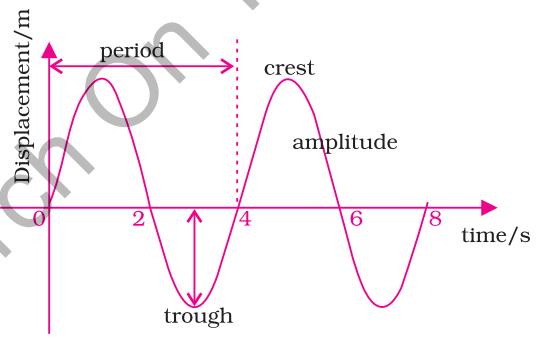
Chapter 14

WAVE MOTION AND SOUND

Wave motion, examples of waves, characteristics of waves, orientation of particle motion and types of waves, medium and types of waves, characteristics of sound, types of sound waves, factors affecting speed of sound, Mach number reflection of sound, echo, reverberation, interference of sound, Doppler effect, SONAR, musical instruments, human ear and sound, noise and effects.

- **Wave motion :** It is defined as the movement of a distortion of a material or medium, where the individual parts or elements of the material only move to and fro, up and down or in a cyclical pattern.
- It appears as if something is actually moving along the material, but in reality it is just the distortion that moves, where one part influences the next.
- **Examples of waves :** The following examples show common transverse, compression and circular waveforms.
- **Transverse waves :** Up-and-down motion in the form of crest and trough creates transverse waves. Rope or string only moves up-and down, but the wave moves from one end of the rope to the other. A guitar string also has this type of motion in which vibrating string demonstrates waveform.



- Light waves or electromagnetic waves are caused by a up-and-down motion of electric and magnetic fields, thus making them transverse waves.

Compression waves

- Back-and-forth motion creates compression or longitudinal waves. Comparison of compression wave and transverse wave :
- **Slinky :** One can stretch out a slinky along the floor and give one end a back-and-forth shove. The compression will move along the slinky to its other end without the motion of slinky.

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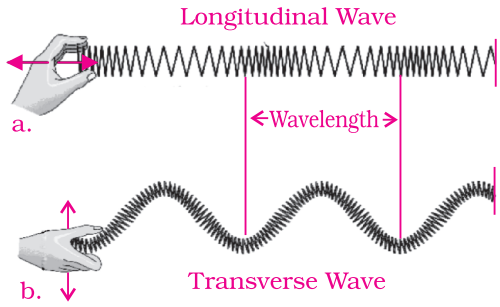
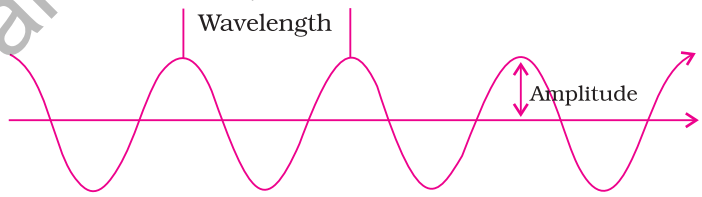
- **Sound waves :** A loudspeaker cone moves back and forth to create a sound, which is also a compression wave.



- **AC electricity :** Electrons move back and forth in a wire, sending a wave of electric power through the wire. The electrons stay in their general region in AC electricity, while they flow through and out of the wire in DC electricity.
- **Circular wave :** There are cases where the material moves in a combination of transverse and compression, moving in a circular or elliptical pattern.
- **Water waves :** When a stone is dropped in a pool, waves move outward. The surface of the water looks like it goes up and down, but actually the water molecules move in a circular or oval motion to form the wave.
- **Characteristics of waves :** The characteristics of a waveform are wavelength, amplitude, velocity and frequency. All periodic waveforms have these common characteristics.
- There are special cases, where only one crest of the wave is seen, like the wave at a ball game or the sound caused by an impact or explosion. In these cases, there is wavelength, but there is no frequency, since the waveform is not periodic.
- **Wavelength :** It is defined as the distance from one crest (or maximum of the wave) to the next successive crest or maximum.



- The wavelength of an ocean wave is typically several metres. The wavelength of the electromagnetic wave used in a microwave oven is in the order of a centimetre or less.
- **Amplitude :** The height of the wave is called its amplitude. Some areas consider the middle of the wave to its peak as the amplitude, while others consider peak to peak as the amplitude.

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- Amplitude relates to loudness in sound and brightness in light.
- **Velocity or speed :** It is the measurement of how fast a crest or trough is moving from a fixed point.
- For example, the velocity of water waves can be measured as their speed in a given direction with respect to the land. Also, the velocity or speed of sound waves is about 1000 feet/second, while the speed of light is 186,000 miles/second.

  Velocity = wavelength × frequency : $v = \lambda \times f$

  where v is the velocity in metres/second (m/s) or feet/second (ft/s)

  λ (Greek letter small-lambda) is the wavelength in m or ft.

  f is the frequency is cycles per second or hertz (Hz).
- Units for velocity may be other multiples, such as km/s or m/s. Wavelength units must correspond with velocity units.
- **Frequency :** It is the rate, the crests or peaks pass a given point in a unit time. Frequency is the velocity divided by the wavelength designated as cycles (or peaks) per second. Cycles per second is also called hertz.

  $f = v/\lambda$
- **Period :** The frequency is also the reciprocal of the time between crests passing a point or the period of the vibration. In measurement: $f = 1/T$, T is the time period of the vibration in seconds.
- **Orientation of particle motion and types of waves :** The waves relative to the direction of energy propagation are of three types :
- **Longitudinal waves :** Movement of the particles is parallel to the direction of energy propagation. Sound waves moving through the air are an example of this type of wave.
- **Transverse waves :** Movement of the particles is at right angles (perpendicular) to the direction of the energy propagation. Movement of a wave through a solid object like a stretched rope or a trampoline are examples of this type of waves including formed by water ripples.
- **Surface waves :** Movement of particles in a circular motion. These waves occur at interfaces. Examples-waves in the ocean and ripples in a cup of water. One consequence of occurring at an interface is that the motion of the particles diminishes with distance from the interface. The farther from the interface, the smaller the rotation of the particles until as some distance from the surface, there is no more movement or energy propagation.
- **Types of waves and medium :** Waves on the basis of the necessity of medium have been classified into two types, electromagnetic and mechanical waves.

1. **Electromagnetic waves** (including light) can move through a vacuum.

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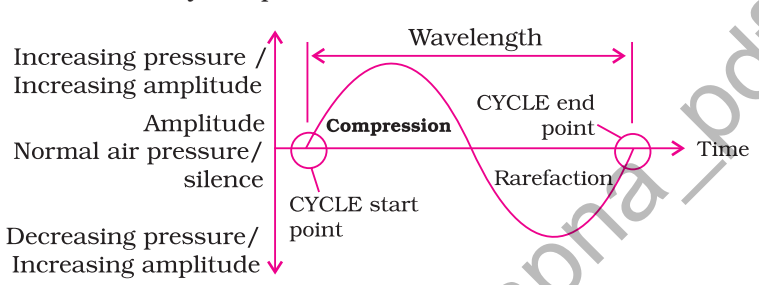
2. **Physical/Mechanical waves** require matter through which to propagate. Physical waves are further distinguished by the phases of matter through which they move. Longitudinal waves can pass through liquids and gases while transverse waves require a material to be solid to propagate.

- **Sound waves :** These waves travel as pressure variation in the air, *i.e.* are alternate regions of high density pressure (compression) and low density and pressure (rarefaction)



- **Amplitude :** It refers to the maximum vertical displacement of the wave from its mean position. Larger is the amplitude, the higher is the energy. In sound, amplitude refers to the magnitude of compression and expansion experienced by the medium the sound wave is travelling through. This amplitude is perceived by our ears as loudness. High amplitude is equivalent to loud sounds.
- **Wavelength :** A sound wave is made of the areas of high pressure alternated by an area of low pressure. The high pressure areas are represented as the peaks of the graph. The low pressure areas are depicted in the valleys. The physical distance between two consecutive peaks or valleys in a sound wave is referred to as the wavelength of the sound wave.

- **Frequency/ Pitch of the Sound Waves :** It refers to the rate of the vibration of the sound travelling through the air. This parameter decides whether a sound is perceived as high pitched or low-pitched. In sound, frequency is also known as pitch. The frequency of the vibrating source of sound is calculated in cycles per second. The SI unit for frequency being hertz and it is defined as '1/T' where T refers to the time period of the wave. Wavelength and frequency of a sound wave are related mathematically by wave equation as:

Velocity of Sound = Frequency *x* Wavelength

- Two graphs showing the difference between sound waves with high and low frequencies and their corresponding pitches.

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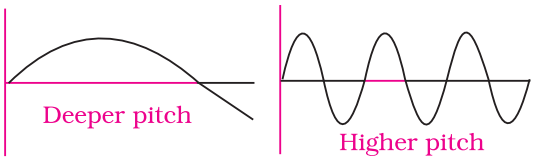

1. **Timbre :** Timbre or quality is actually defined when two different sounds have the same frequency and amplitude, then by definition they have different timbres depending on the source of sound.
2. **Types of sound waves :** Sound waves are divided into three categories that cover different frequency ranges.
3. Audible waves are waves that lie within the range of sensitivity of the human ear. The range is 20Hz to 20,000Hz (20Hz to 20KHz). They can be generated in a variety of ways, such as by musical instruments, human vocal cords and loudspeakers.

- **Infrasonic waves** are waves having frequencies below the audible range, *i.e.* less than 20Hz. Elephants can use infrasonic waves to communicate with one another, even when separated by many kilometres.
- Ultrasonic waves are waves having frequencies above the audible range, *i.e.* above 20KHz. You may have used a "silent" whistle to retrieve your dog. The ultrasonic sound is easily heard by dogs, although humans cannot detect it at all. Bats use these waves for flying at night. Ultrasonic waves are also used in medical imaging in industries to find minute cracks in machine parts, in making of smooth colloids like tooth paste, facial creams etc and in dish washing machines.
- **Factors affecting speed of sound :** A number of factors affect the speed of sound. These include:
- **Medium :** The density of medium affects the speed of sound. With increasing density, the speed of sound increases. Therefore, the speed of sound is maximum in solids and the least in air or gases and none in vacuum.
- **Temperature :** It affects the speed of sound because it affects the "elastic" qualities of different mediums. At the very basics, lower temperatures will decrease the speed of sound while higher temperatures will increase the speed of sound, all other factors being kept constant.
- **Pressure :** The effect of pressure on the speed of sound is due to the inertial properties of the materials. In short, the more pressure that is applied to the material or medium, the denser it becomes and the greater the "inertia" becomes. This makes any interaction between particles slower. Therefore, the speed of sound throughout the medium is slowed due to the greater pressure.
- **Direction of Wind :** The speed of sound increases or decreases according to the direction of wind. If wind is blowing in the direction

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of the propagation of sound, the speed of sound increases; if it is blowing in a direction opposite to that of sound, the speed of sound decreases.

- **Humidity :** The speed of sound in air increases with the increase in humidity in the air. Sound travels faster in humid air than dry air.
- **Reflection of sound waves :** When sound travels in a given medium, it strikes the surface of another medium and bounces back in some other direction. This phenomenon is called the reflection of sound. The waves are called the incident and reflected sound waves.
- The sound waves that travel towards the reflecting surface are called the incident sound waves. The sound waves bounced back from the reflecting surface are called reflected sound waves. A perpendicular drawn on the point of incidence is called the normal. The angle which the incident sound waves makes with the normal is called the angle of incidence, "i". The angle which the reflected sound waves makes with the normal is called the angle of reflection, "r".
- The following two laws of reflection of light are applicable to sound waves as well :
  - The incident wave, the normal to the reflecting surface and the reflected wave at the point of incidence lie in the same plane.
  - The angle of incidence $\angle i$ is equal to the angle of reflection $\angle r$.
- **Echo :** An echo stands for the reflected sound heard by a person. The following conditions ought to be satisfied for the formation of an echo :
  - The size of the obstacle/reflector must be large compared to the wavelength of the incident sound (for reflection of sound to take place).
  - The distance between the source of sound and the reflector in dry air should be at least 17.4 m (so that the echo should be heard distinctly after the original sound is over).
  - The intensity or loudness of the sound should be sufficient for the reflected sound reaching the ear to be audible. The original sound should be of short duration.
- **Reverberation :** It is an echoing sound. When you bang on a big piece of metal, you can hear the reverberation even after you have stoped banging.
- The repeating, often low, booming sound that follows the sound of an electric guitar or the thump of a drumstick on a cymbals is nothing but reverberation. It's frequently described as sound that lingers beyond the original noise.

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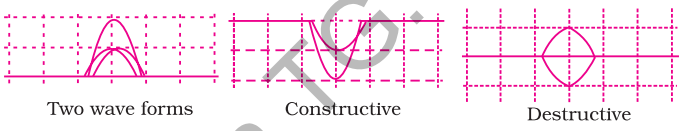
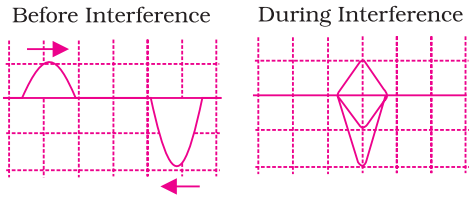
- **Interference of waves :** It is the phenomenon that occurs when two waves meet while travelling along the same medium. The interference of waves causes the medium to take on a shape that results from the net effect of the two individual waves upon the particles of the medium. It can be constructive or destructive interference.
- **Constructive interference :** It is a type of interference that occurs at any location along the medium where the two interfering waves have a displacement in the same direction. In this case, both waves have an upward displacement, consequently, the medium has an upward displacement that is greater than the displacement of the two interfering pulses. Constructive interference is observed at any location where the two interfering waves are displaced upward. But it is also observed when both interfering waves are displaced downward.
- **Destructive interference** is a type of interference that occurs at any location along the medium where the two interfering waves have a displacement in the opposite direction. For instance, when a sine pulse with a maximum displacement of +1 unit meets a sine pulse with a maximum displacement of -1 unit destructive interference occurs. This is depicted in the diagram below.



- In the diagram above, the interfering pulses have the same maximum displacement but in opposite directions. The result is that the two pulses completely destroy each other when they completely overlap. At the instant of complete overlap, there is no resulting displacement of the particles of the medium. although it is not a permanent condition.
- If the two interfering waves do not have equal amplitudes in opposite directions for destructive interference such as a pulse with a maximum displacement of +1 unit meets a pulse with a maximum displacement of -2 units, the resulting displacement during complete overlap will be -1 unit.



Complete destructive interference Partial destructive interference

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- This is still destructive interference since the two interfering pulses have opposite displacements. In this case, the destructive nature of the interference does not lead to complete cancellation but partial destructive interference.
- **Principle of superposition**: It states that when two waves interfere, the resulting displacement of the medium at any location is the algebraic sum of the displacement of the individual waves at that same location such as :

Displacement of Pulse-I	Displacement of Pulse-II	Resultant displacement
+1	+1	+ 2
– 1	–1	– 2
+ 1	–1	0
+1	–2	– 1

- **Doppler effect :** It is observed whenever the source of waves is moving with respect to an observer. The effect can be described as the effect produced by a moving source of waves in which there is an apparent upward shift in frequency for observers towards whom the source is approaching and an apparent downward shift in frequency for observers from whom the source is receding. It is important to note that the effect does not result because of an actual change in the frequency of the source.
- The Doppler effect can be felt when a car approaches with its siren blasting, the pitch of the siren sound (a measure of the siren's frequency) is high and then suddenly after the car has passed by, the pitch of the siren sound becomes low. That is the Doppler effect - an apparent shift in frequency for a sound wave produced by a moving source.
- In astronomy the belief that the universe is expanding is also based on the Doppler effect felt using electromagnetic waves emitted by stars in distant galaxies.
- **Mach number :** In modern physics it is used to denote the speed of aircrafts or other high flying objects. It is defined as the ratio of the speed of a body (aircraft) to the speed of sound in the undisturbed medium through which the body is travelling. If an aircraft is flying at mach-1, then its speed is equal to the speed of sound in air 332 m/s.
- **SONAR :** It stands for Sound Navigation and Ranging. An active sonar uses a sound transmitter and a receiver. When the two are in the same place, it is monostatic operation. When the transmitter and the receiver are separated, it is bistatic operation.

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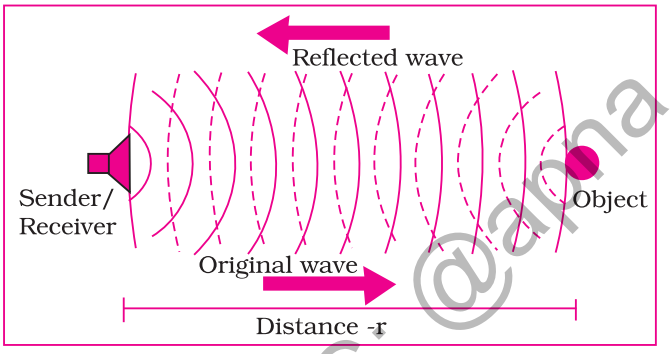
- An active sonar creates a pulse of sound called a "ping", and then listens for reflections (echo) of the pulse. This pulse of sound is generally created electronically using a sonar projector consisting of a signal generator, power amplifier and electro-acoustic transducer/ array. To measure the distance of an object such as depth of an ocean by the fathometer, the time from transmission of a pulse to reception is measured and converted into a range. In single frequency transmissions, the Doppler effect is used for measuring the radial speed of a target such as in submarines. The difference in frequency between the transmitted and received signal is measured and converted into a velocity.



- **Musical instruments :** Musical instruments are grouped into families based on how they produce sounds. The different types of these instruments include :
- **Brass instruments :** These are made of brass or some other metal and make sound when air is blown inside. The musician's lips must buzz, as though making a "raspberry" noise against the mouthpiece. Air then vibrates inside the instrument, which produces a sound. These include trumpet, trombone, tuba, French horn, cornet and bugle.
- **Percussion instruments :** These make sounds when they are hit, such as a drum or a tambourine. Others are shaken, such as maracas, and still others may be rubbed, or scratched, or whatever to make the instrument vibrate and produce a sound. These instruments include drums, cymbals, triangle, chimes, tam-tam, glockenspiel, timpani, bells and xylophone.
- **String instruments :** In these instruments strings need to be plucked, as in a guitar or harp, bowed, as with a cello or a violin; or struck, as with a dulcimer. This creates a vibration that causes a unique sound.
- **Woodwind instruments :** These instruments produce sound when air (wind) is blown inside. Air might be blown across an edge, as with a flute, between a reed and a surface, as with a clarinet or between two reeds, as with a bassoon. The sound is produced when the air vibrates inside. These instruments include the flute, piccolo, clarinet, recorder, bassoon and the oboe.

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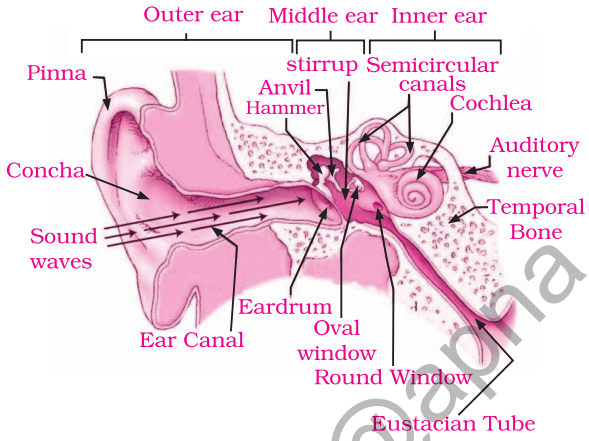
- **Sound and human ears :** The three parts of the ear are the outer ear, the middle ear and the inner ear. The inner ear is also called the cochlea. ('Cochlea' means 'snail' in Latin; the cochlea gets its name from its distinctive coiled up shape like the slope of a snail's shell.)



- The outer ear consists of the pinna, ear canal and eardrum (Tymphanic membrane) The middle ear consists of ossicles (malleus, incus, stapes) and eustacian tube. The three amplify amplifies the sound heard by a person before its transmission to inner ear.
- The inner ear consists of the cochlea, the auditory (hearing) nerve and the brain. In cochlea, Organ of Corti transforms the mechanical signals of vibrations in endolymph to electrical signals for transmission to the brain by auditory nerve.
- Sound waves enter the ear canal and make the ear drum vibrate. This action moves the tiny chain of bones (ossicles – malleus, incus, stapes) in the middle ear. The last bone in this chain the stapes, smallest body bone 'knocks' on the membrane window of the cochlea and makes the fluid in the cochlea move. The fluid movement then triggers a response in the hearing nerve.
- **Noise :** It is most commonly discussed in terms of decibels (dB), the measure of loudness, or intensity of a sound; this measurement describes the amplitude of a sound wave. On the other hand, pitch describes the frequency of a sound and is measured in hertz (Hz).
- Any sound in range of 80dB-90dB is considered as noise.
- Exposure to noise is associated with several negative health outcomes. Depending on duration and level of exposure, noise may promote hearing loss, high blood pressure, ischemic heart disease, sleep disturbances, birth defects, and even decreased school performance.

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Chapter 15

LIGHT AND ITS PROPERTIES

PHYSICS

Different sources of light, reflection of light, image formation by plane mirror, concave mirror and convex mirror, refraction by a glass slab, image formation by concave and convex lens, microscope, telescope and types, human eye and eye defects, interference of light by single slit, double slit, diffraction v/s interference, polarization of light, spectrum and types, facts about light.

- **Sources of light :** The objects have broadly been classified as luminous (light-emitting) and non-luminous (non-light emitting). The luminous objects further based on the source and mode of emission of light have further been classified as:
- **Electric discharge** such as electric spark in internal combustion engines lightning, fluorescent lamps, mercury-vapour lamp, sodium-vapour lamp, etc
- **Incandescence :** These sources of light include black-body radiation, earthquake light, halogen lamp and traditional Incandescent light bulb with a filament, volcanic eruption and lava released is also an example of incandescent source of light.
- **Combustion :** The combustion of fossil fuels such as in gas lighting, kerosene lamps, lanterns and oil lamps. The others include Bunsen burner, candle, fire, fireworks, torch and explosives.
- **Celestial :** Nebula and stars, the Milky Way, and a shooting star, Sun (sunlight, solar radiation), Aurorae, are the sources of celestial light.
- **Luminescence :** It is the emission of light by a substance not resulting from heat. There are different forms of it such as:
- **Chemiluminescence :** It is light resulting from a chemical reaction such as during the oxidation of reactive metals like sodium.
- **Bioluminescence :** It is the emission of light resulting from biochemical reaction in a living organism such as in *Aequorea victoria, Antarctic krill*, fox fire, glow-worm and electric ray fish.
- **Electroluminescence :** It is the emission of light resulting from an electric current passed through a substance such as light-emitting diodes (LED) and LASER's. (Light Amplitication by Stimulated Emission of Radiation)
- **Photoluminescence :** Photoluminescence is light resulting from absorption of photons, the packet of energy carried by light such as photoelectricity.
- **Thermoluminescence :** It is light from the reemission of absorbed energy when a substance is heated.

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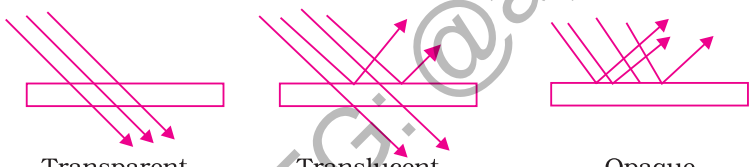
- **Lambert's Cosine law :** According to this law if E is the illuminance, *i.e.* brightness of surface then

$$E = \frac{I \cos \theta}{r^2}$$

where 'θ' is angle of incidence, r is the distance of screen from source, I is luminous intensity. In MKS, the S.I. unit of E is candela/metre^2

Fluorescence v/s Phosphorescence :

- **Phosphorescence :** Certain substances continue to emit light even after the incident light is cut off. This phenomenon is called phosphorescence, e.g. cadmium sulphide, strontium sulphide.
- **Fluorescence :** The phenomenon of converting radiation of smaller wavelength into radiation of longer wavelength, e.g., petrol, zinc sulphide, uranium oxide, quinine sulphate, barium platino cyanide, calcium fluoride and paraffin oil.
- **Reflection and types of objects :** The objects based on the percentage of light reflected by them have been classified as transparent, translucent and opaque.



Transparent Translucent Opaque

- **Reflection of light :** Reflection takes place when light bounces off by an opaque object. If the surface is smooth and shiny, like glass, water or polished metal, the light will reflect at the same angle as it hits the surface. This is called specular reflection.
- **Types of reflection :** The reflection based on the nature of the reflecting surface can be regular or diffused.
- **Regular reflection :** It takes place when the surface is smooth or plane. It is difficult for a person to see in the regular reflected light because of the glare produced or dazzling effect.
- **Diffused reflection** takes places when light hits an object and reflects it in lots of different directions. This happens when the surface is slightly rough. Most of the things we see are because light from a source has been reflected by it.
- **Specular reflection :** The angle at which light hits a reflecting surface is called the angle of incidence, and the angle at which light bounces off a reflecting surface is called the angle of reflection. The angle of incidence and reflection are measured with respect to the normal. Normal is the perpendicular drawn on the reflecting surface at the point of incidence.

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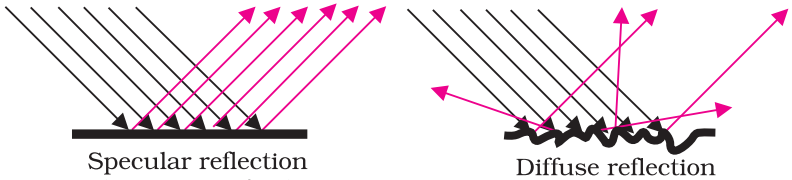
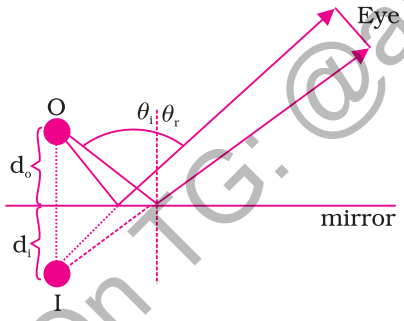


Specular reflection (smooth surface) — Diffuse reflection (rough surface)

- **Laws of reflection:** These laws proposed by Euclid , a state that
  - the incident ray, reflected ray and normal lie in the same plane.
  - the angle of incidence is always equal to the angle of reflection, *i.e.* if $\angle i = 30^0$, $\angle r = 30°$, *i.e.* the angle between incident and reflected ray is 60^0 or the angle between incident or reflected ray and interface is 60°.
- **Image formation by plane mirror :** The different features of the image formed by a plane mirror includes:
  - The image is formed behind the mirror.
  - The image is virtual, *i.e.* cannot be taken on screen.



  - The image is of the same size as the object.
  - The image is upright, with the same altitude as the object.
  - The image undergoes a lateral inversion in relation to the object, *i.e.* right side appears left and vice versa.
  - The image is situated at the same distance in the mirror as the object in front of it.

Therefore :

- when a person approaches a mirror with velocity of x m/s, his image approaches the person with velocity of 2x m/s.
- when a person stands with his right hand holding a razor, the image appears to show the left hand holding the razor.
- if a person standing in front of a mirror wishes to see his full size image, the size of the mirror has to be minimum half of his length in height.
- the number of images formed when two plane mirrors are placed at an angle is

$$\text{Number of images} = \left[\frac{360°}{\theta(\text{angle between mirrors})}\right] - 1$$

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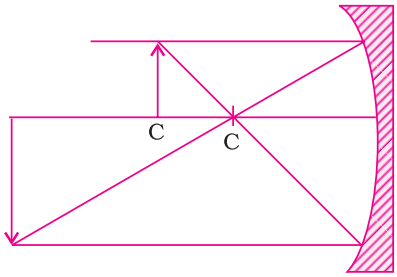
- **Concave mirrors :** The inside curve of a spoon is an example of a concave mirror.These mirrors are used in certain types of astronomical telescopes called reflecting telescopes. The mirrors condense lots of light from faint sources in space onto a much smaller viewing area and allow the viewer to see far-off objects and events in space that would be invisible to the naked eye.

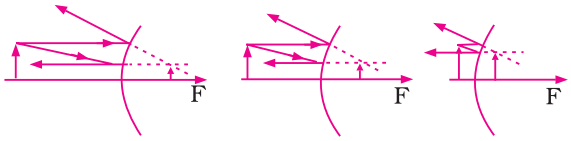


- Light rays travel towards the mirror in a straight line and are reflected inwards to meet at a point called the focal point.
- Concave mirrors are useful as make-up mirrors because they can make things seem larger. Therefore, concave shape is also useful for car headlights and satellite dishes.
- Dentists also use concave mirrors for the magnified view of a tooth.

Objective position	Image position	Size of image	Nature of image
At infinity	Focus (F)	Point-sized	Real
Beyond C	Between F and C	Small	Real and inverted
At C	At C	Same as that of the object	Real and inverted
Between C and F	Behind C	Magnified	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between F and P	Behind mirror	Magnified	Virtual and erect

(C-Centre of Curvature, F-Focal point, P-Plane of mirror)

- **Convex mirrors:** Convex mirrors curve outwards, like the outside of a balloon or a spoon.
- Parallel rays of light strike the mirror and are reflected outwards. If imaginary lines are traced back, they appear to come from a focal point behind the mirror. Convex mirrors irrespective of the size or position of an object from the mirror always produce a diminished and virtual image between the pole of mirror and its focus.



- Convex mirrors are useful for shop security as anti-theft mirror and rear-view mirrors on vehicles because they give a wider field of vision.

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- **Scattering of light :** Some light is scattered in all directions when it hits very small particles such as gas molecules or much larger particles like dust or droplets of water.
- The amount of scattering depends on how big the particle is compared to the wavelength of light that is hitting it. Smaller wavelengths are scattered more.
- **Sky appears blue :** Light from the sun is made of all the colours of the rainbow. As this light hits the particles of nitrogen and oxygen in our atmosphere, it is scattered in all directions. Blue light has a smaller wavelength than red light, so it is scattered much more than red light. Therefore, when we look at the sky, we see all the places blue unless an object emits its own colour.
- **Sunsets appear red :** When the sun appears lower in the sky, the light that reaches us has already travelled through a lot more of the atmosphere. This means that a lot of the blue light has been scattered out well before the light arrives at us, so the sky appears red. Moreover, red light travels faster than other crsible colour.
- **Clouds are white :** Clouds appear white because the water droplets are much larger than the wavelengths of light. For this situation, all wavelengths of light are equally scattered in all directions. The blend of all colours of light gives an impression of white light.
- **Mirror Equation and the Magnification Equation :** The mirror equation expresses the quantitative relationship between the object distance (d_o), the image distance (d_i) and the focal length (f). The equation is stated as follows:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \text{ or } \frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

- The magnification equation relates the ratio of the image distance and object distance to the ratio of the image height (h_i) and object height (h_o). The magnification equation is stated as follows:

$$m = \frac{h_i}{h_o} = v$$

- These two equations can be combined to yield information about the image distance and image magnitication, + ve or –ve if the object distance, object height and focal length are known.

Problem : A 4.00 cm tall light bulb is placed a distance of 45.7 cm from a concave mirror having a focal length of 15.2 cm. Determine the image distance and the image size.

Solution : $h_o = 4.0\ cm$ $\quad d_o(u) = 45.7\ cm\ f = 15.2\ cm$

$d_i(v) = ?$ $\quad h_i = ?$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \qquad \frac{1}{15.2} = \frac{1}{v} + \frac{1}{45.7}$$

$v = 22.8$ cm

With $h_i/h_o = -\ d_i/d_o$

$h_i/(4.0\ cm) = -\ (22.8\ cm)/(45.7\ cm)$

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h_i = - (4.0 *cm*) × (22.8 *cm*)/(45.7 *cm*)
h_i = -1.99 *cm*

Problem : Determine the focal length of a convex mirror that produces an image which is 16.0 cm behind the mirror when the object is 28.5 cm from the mirror.

Solution : Using the equation $1 / f = 1 / d_o + 1 / d_i$
where d_o = 28.5 *cm* and d_i = -16.0 *cm*
substituting the values and solving for *f*, *f* = -36.6 *cm*

- **Refraction of light :** It refers to the bending of a ray of light when it enters a medium where its speed is different. When a ray passes from a rare into denser medium, it bends towards the normal and vice versa. The amount of bending depends on the indices of refraction of the two media and is quantitatively by Snell's law. In the denser medium, although the frequency remains unaffected , it's the wavelength that is reduced to reduce the speed of light.
- The refractive index (*n*) of a medium is the ratio of the speed of light in vacuum, *i.e.* 3×10^8m/s to the speed of light in the medium.

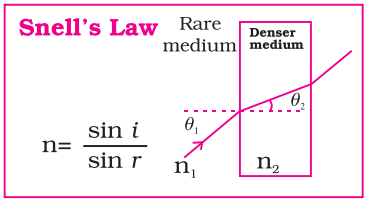
$$n = c/v$$

- where *c* is the speed of light in vacuum and *v* is the speed of light in the medium. The refractive indices of some of the mediums is listed in the table given below.

Material	n	Material	n
Vacuum	1.000	Ethyl alcohol	1.362
Air	1.000277	Glycerin	1.473
Water	$\frac{4}{3}$ = 1.333	Ice	1.31
Carbon disulphide	1.63	Polystyrene	1.59
Methylene iodide	1.74	Crown glass	1.50-1.62

Laws of refraction: These laws state that

- The incident ray, refracted ray and normal lie in the same plane.
- The 2nd law, also called as Snell's law, states that the ratio of sin *i* to sin *r* called refractive index is constant for any two given mediums.



- **Refraction of light through a glass slab :** The figure shows the refraction of light through a X' O' rectangular glass slab ABCD. XO is incident Y ray, OO' is the refracted ray and O'Y is the emergent ray. The angle of incidence (i) is always equal to the angle of emergence (r_2) the two medium being same having equal refractive index. The ray XX' represents the lateral displacement which depends on the thickness of the slab, refractive index angle of incidence and refraction.

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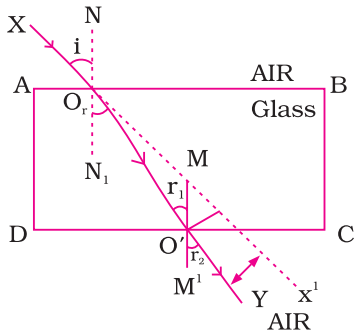


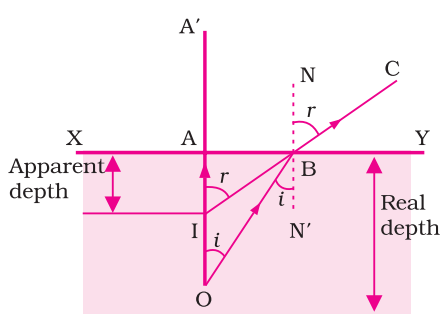
$$d = \frac{t}{\cos r}(i - \sin r)$$

where d is the lateral displacement, t is the thickness of glass slab and r is the angle of refraction. This also shows that the lateral displacement is proportional to the thickness of the slab.

1. **Behaviour of rays of light between two different mediums :** As you have studied above, when a ray light is passing from air to glass, that is from a rarer medium to a denser medium the refracted ray bends towards the normal drawn at the point of incidence.
   In this case $\angle i > \angle r$. But when the ray of light passes from glass to air, that is from a denser medium to a rarer medium, the refracted ray bends away from the normal. In this case $\angle r > \angle i$.
2. The elementary ray *OY* which is nothing but the refracted ray emerging out of the glass slab is parallel to the incident ray. This means that the refracted ray has been displaced from its original path by a distance d. This displacement is referred to as lateral displacement.

➢ **Real depth and apparent depth :** The figure shows the difference between the real depth and apparent depth of the object under water. When an observer watches an object immersed in water, he sees the image of an object such as fish at the distance AI from the surface which is the apparent depth of the fish because of the refraction of light.

$$\text{Refractive index} = \frac{\text{Real depth}}{\text{Apparent depth}}$$



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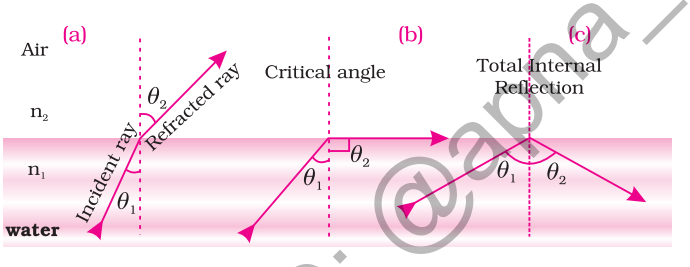
- **Total internal reflection :** When a ray of light passs from a rarer into denser medium, it gets refracted towards the normal. Conversely from denser medium into rare medium, it refracts away from the normal.
- Total internal reflection is the phenomenon in which light rays travel from a denser medium into a rare dense medium (e.g. glass to air or water to air).
- With the increasing angle of incidence, the angle of refraction increases too. When the angle of incidence reaches a value known as the **critical angle,** the refracted rays travel along the surface of the medium or in other words are refracted to an angle of 90°, e.g., the critical angle for the angle of incidence in glass is 42°.



- When the angle of incidence exceeds critical angle, total internal reflection takes place as the refracted ray after deviation passes through the same medium. (C).

Applications of total internal refraction of light:

- Total internal reflection is the operating principle of optical fibers, which are used in endoscopy and telecommunications.
- Total internal reflection is the operating principle of automotive rain sensors, which control automatic windscreen/windshield wipers.
- Total internal reflection is the spatial filtering of light.
- Prisms in binoculars use total internal reflection, rather than reflective coatings, to fold optical paths and show erect images.
- Optical finger printing devices use total internal reflection in order to record an image of a person's fingerprint without the use of ink.
- A total internal reflection fluorescence microscope uses the incadescent wave produced by TIR to excite fluorophores close to a surface. This is useful for the study of the surface properties of biological samples.
- Total internal reflection is the operating principle of LED Light Panels. This technology utilizes LGPs (Light Guide Plates) as

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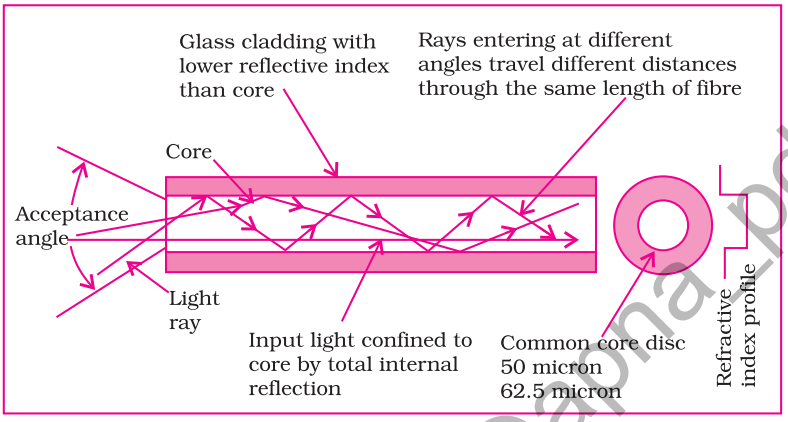
the vehicle for transmitting light over large areas. By etching a grid pattern on the second surface of the LGP, frustrated total internal reflection occurs allowing the light to escape the LGP as visible illumination.



- Diamonds shine due to total internal reflection.
- **Optical fibre :** The main part of the cable-in the middle is called the core and that's the bit the light travels through. Wrapped around the outside of the core is another layer of glass called the cladding. The job of cladding is to keep the light signals inside the core. It can do this because it is made of a different type of glass than core, mostly have low refractive index.

- **Gastroscope** (a type of endoscope), which doctors poke down someone's throat for detecting illness inside his/her stomach. A gastroscope is a thick fibre-optic cable consisting of many optical fibres. At the top end of a gastroscope, there is an eyepiece and a lamp. The lamp shines its light down one part of the cable into the patient's stomach. When the light reaches the stomach, it reflects off the stomach walls into a lens at the bottom of the cable which then travel back up another part of the cable into the doctor's eyepiece. Other types of endoscopes work the same way and can be used for inspecting different parts of the body. There is also an industrial version of the tool, called a fibrescope, which is used for examining things like inaccessible pieces of machinery in airplane engines.
- Refraction through a convex lens : A convex lens is thicker at the centre than at the edges. Ray of light passing through the lens is brought closer, *i.e.* converged at a point called the principal focus. Hence, these lenses are also called converging lenses. The distance between the principal focus and the centre of the lens is called focal length.

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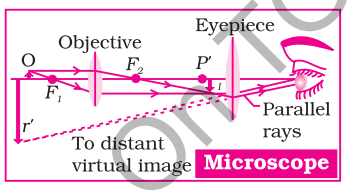
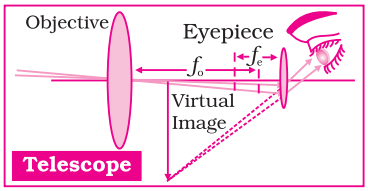
Objective position	Image position	Size of image	Nature of image
At infinity	At F_2	Extremely small	Real and inverted
Behind $2F_1$	Between F_2 and $2F_2$	Small	Real and inverted
At $2F_1$	At $2F_2$	Same as that of the object	Real and inverted
Between $2F_1$ and F_1	Beyond $2F_2$	Magnified	Real and inverted
At F_1	At infinity	Highly enlarged	Real and inverted
Between F1 and O	Same side on the lens	Magnified	Virtual and erect

➢ **Uses of Convex Lenses –** These lens are used :

- ❖ in the camera and digital camera , an optical device used for producing a diminished, real and inverted image on the film.
- ❖ as a magnifying glass which produces a magnified (larger) image of an object. For a convex lens to produce a virtual, erect and magnified image, it is a must that the object is placed between the focus and optical centre of the lens.
- ❖ in the microscope and telescope. Both of these devices use the objective lens and eyepiece which are convex lens.





Difference between compound microscope and astronomical telescope:

Compound microscope	Astronomical telescope
Objective lens has smaller focal length, than the eyepiece.	Objective lens has larger focal length than the eyepiece.
Distance between the objective lens and the eyepiece is greater than $f_0 + f_e$.	Distance between the objective lens and the eyepiece is equal to $f_0 + f_e$.
It is used to see very small objects.	It is used to see distant astronomical objects.

➢ **Concave lens :** A concave lens is thinner at the centre than at the edges. Rays of light that pass through the lens are spread out; they diverge, hence, the lens is also called diverging lens. When parallel rays of light pass through a concave lens, the refracted

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rays diverge so that they may appear to come from one point called the principal focus. The distance between the principal focus and the centre of the lens is called the focal length. The image formed irrespective of its size and distance from optical centre is virtual, erect and diminished.

- **Magnification :** The magnification of a lens can be calculated using the formula:

  $$\text{Magnification} = \frac{\text{height of image}}{\text{height of object}}$$

- As this is a ratio between heights, it has no units. A magnification of 2 means the image is twice the size of the object and a magnification of 1 indicates an image size being the same as the object size.
- Optical magnification is the ratio between the apparent size of an object (or its size in an image) and its true size. It is a number only.
- Single lens : The linear magnification of a thin lens is

  $$M = \frac{F}{f_o - d_o}$$

  where f is the focal length and d_o is the distance from the lens to the object. Note that for real images, M is negative and the image is inverted. For virtual images, M is positive and the image is upright.
- The angular magnification of the microscope is given by $M = M_o \times M_e$

  where M_o is the magnification of the objective and M_e the magnification of the eyepiece. The magnification of the objective depends on its focal length f_o and on the distance d between objectives focal plane and the focal plane of the eyepiece (called the tube length)

  $$M = \frac{d}{F_o}$$

- **Telescope :** It is used for seeing distant objects.
- Astronomical telescope is used to see heavenly bodies.

  $f_{objective} > f_{eyelens}$ and $d_{objective} > d_{eyelens}$
- Intermediate image is real, inverted and small but final image is virtual, inverted and small.

  General magnifying power M of an astronomical telescope

  $$M = \frac{V_O}{V_e}$$

  for normal vision : $M = \frac{-f_O}{f_e}$

  for distinct vision : $M = \frac{-f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

  In normal adjustment, length of telescope, $L = f_o + f_e$

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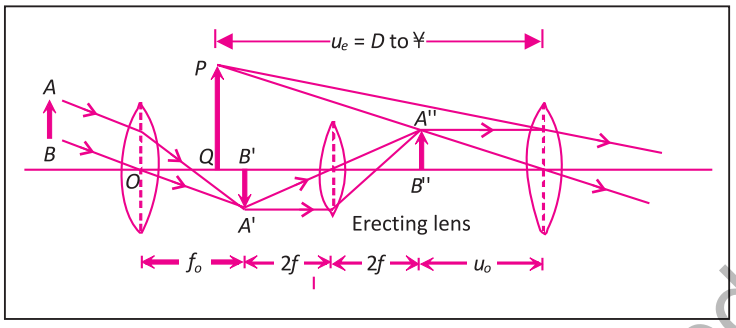

- **Terrestrial telescope :** It is used for seeing far off object on the earth. It consists of three converging lens : objective, eye lens and erecting lens to produce a virtual erect and smaller image. The order of their focal length's is $f_o > f_e > f$.

  Magnification : $m_D = -\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)$ and $m\infty = -\frac{f_o}{f_e}$

  Length : $L_D = f_O + 4f + u_e = f_O + 4f + \frac{f_e D}{f_e + D}$

  and $L\infty = f_o + 4f + f_e$

- **Power of a lens :** Power is measured in dioptres, D, and is given by the formula : P = I / f
  where f equals the focal length of the lens in metre. This is the distance between the lens and the point where an image will be in focus, if the wavefronts entering the other side of the lens are parallel. For a convex lens, the value of power of lens is in positive while negative for a concave lens.
  Problem : A real object is 15 cm from a converging lens of focal length 25 cm. Where is the image formed? Describe it.
  Solution : Light diverges from a real object, so the initial convergence is negative.

  $$C_1 = -1/15 \text{ cm}^{-1}.$$

- The power of the converging lens is $P = +1/25 \text{ cm}^{-1}$.
- The final convergence is = -1/15 + 1/25 = -2/75 cm^{-1}.
- The image is 37.5 cm from the lens. Light is diverging after it has left the lens. The image is on the same side of the lens as the object is. It is a virtual image. The magnification is $C_1/C_2 = +2.5$.
- The image is erect and magnified in size.
- **Problem :** The figure shows that a convergent lens placed inside a cell is filled with a liquid. The lens has focal length +20 cm when in air and its material has refractive index 1.50. If the liquid has refractive index 1.60, what is the focal length of the system?

  Solution: Here $\frac{1}{f_1} = (1.6-1)\left(\frac{1}{\infty} - \frac{1}{20}\right) = \frac{-3}{100}$ .....(i)

  $\frac{1}{f_2} = (1.5-1)\left(\frac{1}{20} - \frac{1}{-20}\right) = \frac{1}{20}$ .....(ii)

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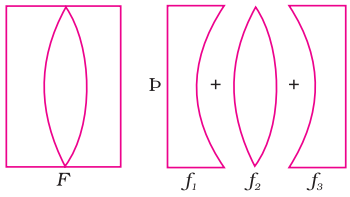
$$\frac{1}{f_3} = (1.6-1)\left(\frac{1}{-20} - \frac{1}{\infty}\right) = \frac{-3}{100} \quad \text{.....(iii)}$$

By using $\frac{1}{F} = +\frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$

Þ $\Rightarrow \frac{1}{F} = +\frac{-3}{100} + \frac{1}{20} - \frac{3}{100}$

$\Rightarrow F = -100cm$



Problem : A 4.00-cm tall light bulb is placed at distance of 8.30 cm from a double convex lens having a focal length of 15.2 cm. Determine the image distance and the image size.

Solution : $h_o = 4.00\ cm$ $\quad d_o = 8.3\ cm$ $\quad f = 15.2\ cm$

$d_e = ?$ $\quad h_e = ?$

$\frac{1}{f} = +\frac{1}{v} + \frac{1}{u}$

$\frac{1}{15.2} = \frac{1}{8.30} + \frac{3}{100}$

$d_i = -18.3\ cm$

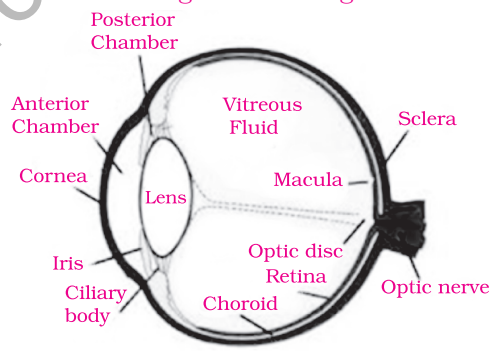
$h_1/h_o = -d_1/d_o$

$h_i/4.00cm = -(-18.3\ cm)\ (8.30\ cm)$

$h_i = 4.00\ cm\ /(18.3cm)\ (8.30\ cm)$

$h_i = 8.81\ cm$

- **Human eye, Structure and working :** The human eye (24 – 25mm in diameter) is the organ which gives the sense of sight, allowing us to observe and learn about the surroundings. The eyes allow us to see and interpret the shapes, colours, and the dimensions of an object. The eye is able to detect bright and dim light, but are the most sensitive to visible light of wavelength 5500 A° *i.e.* yellow light.



- Light waves from an object enter the eye first through cornea, a clear dome-shaped structure the front of eye. Cornea is responsible

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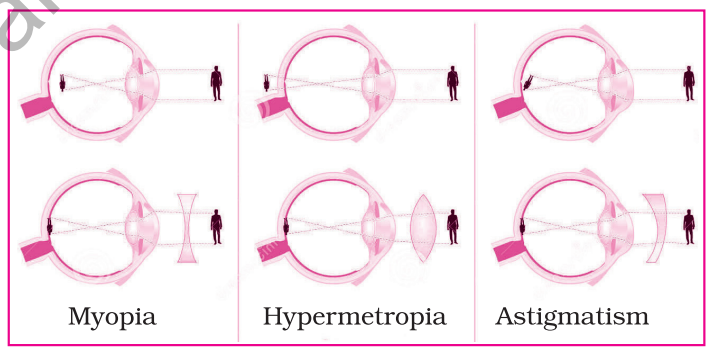
for the maximum refraction of light incidents on eye. The light then passes through the pupil, the circular opening in the centre of the coloured iris. Fluctuations in the intensity of incoming light change the size of the eye's pupil. Pupil controls the amount of light that enters into the eye. As the light entering the eye becomes brighter, the pupil constricts, due to papillary light response while as the light gets dimmer, the pupil dilates. The crystalline biconvex lens that is located behind the iris and pupil, the image is inverted and reversed. From here, the light continues through the vitreous humour, the clear gel that makes up 80% of the eye volume, and ideally, back to a clear focus on the retina. The smallest area of the retina called macula provides the best vision of any location in the retina. Within the layers of retina, light impulses are changed by rod cells and cone cells into electrical signals to be carried by the optic nerve to brain for interpretation.

- **Eye defects :** Humans normally suffer from myopia , hypermetropia, astigmatism and old-age prebyopia.

Myopia	Hypermetropia
Near-sightedness, a person can clearly see nearby objects but not distant objects	Far-sightedness, a person can clearly see distant objects but not nearby objects
The image is formed in front of the retina.	The image is formed behind the retina.
The focal length of the eye lens increases.	The focal length of the eye lens decreases.
It is corrected by concave lens of suitable focal length/power.	It is corrected by convex lens of suitable focal lengh/power.

- **Astigmatism :** In this defect, one or more surfaces of the cornea or eye lens are not spherical but, instead, are rough. As a result of which ,there is no distinct focus inside and the person fails to visualize the proper dimension of the object. It is corrected by using cylindrical lenses.



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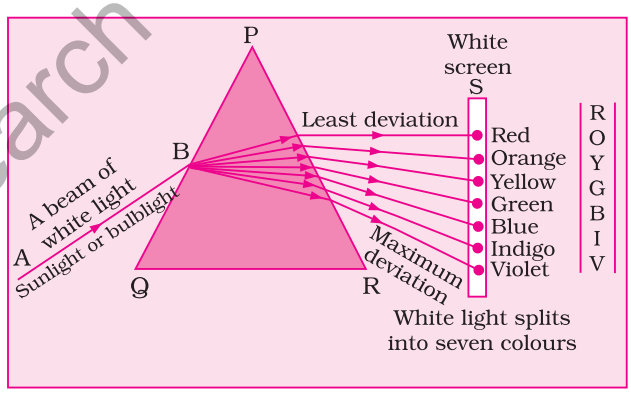
- **Presbyopia :** Among humans after the age of 45 years, eyes are most likely to be affected by presbyopia because of the lessening flexibility of eye lens along with weakening ciliary muscles which control the eye lens focal length. It is corrected using glasses having bifocal lens. in which upper part is concave and lower is convex lens.
- **Braille system for blind :** It was developed by louis Braille in 1821 but was adopted years later in 1932. The system has 63 dot patterns or characters in which each character represents a letter-these patterns are embossed on Braille sheet to recognize them by touchig with dots slightly raised, In India Ravindra Jain obtained his Sangeet Prabhakar degree, Lal Advani, himself visually challenged represented India in UNESCO on Braille problem. Helen A. Keller an American author and lecturer wrote books in cheding "story of my life."
- **Dispersion :** Dispersion is the splitting up of white light into seven colours on passing through a transparent medium like a glass prism. When a white light beam is passed through a prism, a band of seven colours is formed, known as the spectrum of white light. The seven colours in the spectrum are red, orange, yellow, green, blue, indigo and violet respectively.
- The formation of the spectrum of seven colours shows that white light is a mixture of seven colours of light.These seven colours can be viewed using a solid prism. A hollow prism does not cause any dispersion of light because for a hollow prism $A \neq O$ but $\delta = O$.
- **Rainbow :** It is an arch of seven colours visible in the sky which is produced by the dispersion of sunlight by water drop lets in the atmosphere. These water droplets in atmosphere act as very small glass prisms. The rainbow is actually a natural spectrum of sunlight in the sky splitting the sunlight into a spectrum.



- **Conditions for interference :** When waves come together, they can interfere constructively or destructively. To set up a stable and clear interference pattern, two conditions must be met:

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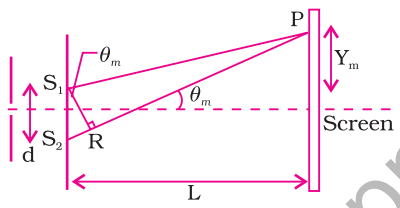
- The sources of the waves must be coherent, *i.e.* they emit identical waves with a constant phase difference.
- The waves should be monochromatic i.e., they should be of a single wavelength.

➢ **Interference of light waves :** The first person to observe and describe the interference of light was Thomas Young in 1801. He used sunlight passing through two closely spaced slits. It was a difficult experiment since the source was not even close to being monochromatic, but Young's double-slit experiment provided the first indisputable evidence of light acting as a wave.

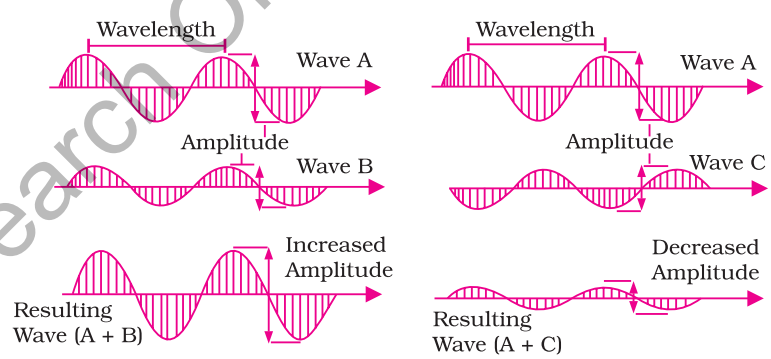


➢ When two sources send out identical waves in phase, both constructive and destructive interference occur. Whether constructive or destructive interference occurs at a point near the sources depends on the path-length difference, d, which is the distance from the point to one source minus the distance from the point to the other source.

➢ Condition for constructive interference: $d\sin\theta = m\lambda$ where m is any integer.

Condition for destructive interference: $d\sin\theta = (m + \frac{1}{2})$

Interference Between Coincident Light Waves



Constructive Interference **Destructive Interference**

➢ If the entire arrangement of Young's double slit experiment is immersed in water, then fringes width decreases

$$\beta_{water} = \frac{\lambda_{water} D}{d} \text{ and } \lambda_{water} = \frac{\lambda_{air}}{a_{\mu_\omega}}$$

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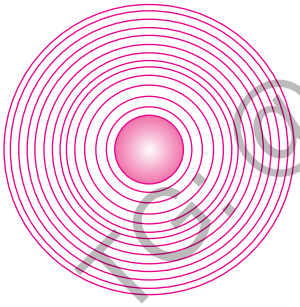
$$\therefore \frac{\beta_{water}}{Pair} = \frac{\lambda_{water}}{\lambda_{air}} = \frac{1}{a_{\mu_\omega}} = \frac{1}{4/3} = \frac{3}{4}$$

$$i.e.\ \beta_{water} = \frac{3}{4}\beta_{air}$$

- If monochromatic light source in Young's double slit experment is replaced by a white light source, then the central frings will be white while some coloured fringes formation may occur around central white fringe.
- It a thin glass sheet or mica sheet is placed infront of one of the two slits, the central fringe will shift towards the slit in front of which glass plate or mica sheet is placed.
- **Newton's rings :** These rings refer to a pattern of wave interference caused by the reflection of light between round and flat surfaces. The phenomenon is named after Sir Isaac Newton, who first studied the pattern in 1717. When viewed with the light of a single colour, the rings look like a series of concentric circles.



- When viewed with white light, the pattern of Newton's rings shows many colours due to the differing wavelengths of light between the two surfaces. Interference between the light rays reflected from the two surfaces causes the light rings to appear differently. The outer rings are closer together than the inner rings, and the distance between the rings corresponds to increase in the thickness of the layer of air.
- **Oily films and interference :** A strangely beautiful pattern of colours is observed when light interacts with an oily substance, as when light reflected on a soap bubble produces an astonishing array of shades. Sometimes, an oily film in a parking lot, left there by a leaky crankcase of a car, produces a rainbow of colours if the sunlight hits it just right.
- This happens because the thickness of the oil causes a delay in reflection of the light beam. Some colours pass through the film, becoming delayed and, thus, getting out of phase with the reflected light on the surface of the film. These shades destructively interfere to such an extent that the waves are cancelled, rendering them invisible. Other colours reflect off the surface so that they are perfectly in phase with the light travelling through the film, and appear as an attractive swirl of colour on the surface of the oil.
- The phenomenon of light-wave interference with oily or filmy surfaces has the effect of filtering light, and, thus, has a number of applications in areas relating to optics: sunglasses, lenses for binoculars or cameras, and even visors for astronauts.

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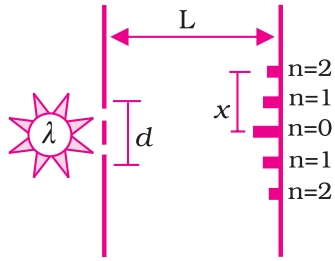
- **Using of Young's double-slit formula**: The formula used in double slit experiment is

$$\lambda = \frac{d}{nL}$$



λ = wavelength of light used (m)

x = distance from central fringe (m)

d = distance between the slits (m)

n = the order of the fringe

L = length from the screen with slits to the viewing screen (m)

- For light of wavelength λ, for reflected light during film formation, constructive interference occur when

$$2\mu t \cos r = (2n-1)\frac{\lambda}{2}$$

destructive interference occurs when

$$2\mu t \cos r = 2n\left(\frac{\lambda}{2}\right)$$

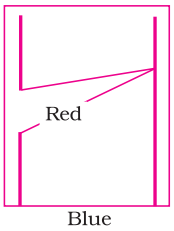
Problem : A pair of screens is placed 13.7m apart. A third order fringe is seen on the screen 2.50cm from the central fringe. If the slits were cut 0.0960 cm apart, determine the wavelength of this light. Roughly what colour will it be?

Solution : L = 13.7 m

n = 3

x = 2.50cm = 0.0250 m

d = 0.0960cm = 9.60 x 10^{-4}m



$$\lambda = \frac{d}{nL}$$

$$\lambda = \frac{0.0250 \times 9.60\times10^{-4}}{3 \times 13.7}$$

$$\lambda = 5.8 \times 10^{-7} \text{ m} = 584 \text{ nm}$$

- **The Single Slit :** The same effect as with doube slit is observed using a single slit.
  - Light from different ends of the slit will be travelling to the same spot on the screen and reach there either in or out of sync. The blue path has to travel farther than the red path. if this difference is equal half of a wavelength, they will meet each other out of sync.
  - If they meet crest to crest or trough to trough, they will be in sync, but if they meet crest to trough they will be out of sync.
  - Being in sync will result in constructive interference, while meeting out of sync will result in destructive interference.

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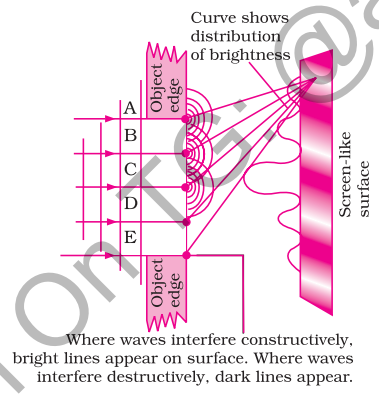
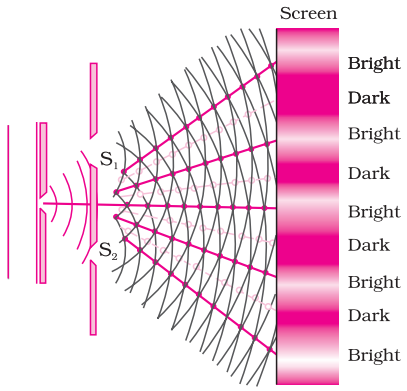
- The result is the same interference pattern, although the effect isn't nearly as dramatic or clear as the double slit experiment.

- After the first couple of fringes (n = 1 and 2), the edges start getting really fuzzy, hence, giving hard time measuring anything. The only real difference in calculations is that "d" is now the width of the single opening.
- **Interference v/s Diffraction of light :** Interference and diffraction of light are different as :
  - Two separate wave fronts originating from two coherent sources produce interference. Secondary wavelets originating from different parts of the same wave front constitute diffraction. Hence, these two are entirely different in nature.
  - The region of minimum intensity is perfectly dark in interference but in diffraction they are not perfectly dark.
  - Width of the fringes is equal in interference but in diffraction they are never equal.
  - The intensity of all positions of maxima are of the same intensity in interference but in case of diffraction they do vary.

Diffraction Pattern



Interference Patterns



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Examples of diffraction :

- Diffraction in the atmosphere by small particles causes a bright ring to be visible around a bright light source like the sun or the moon.
- A shadow of a solid object, using light from a compact source, shows small fringes near its edges such as the speckle pattern which is observed when laser light falls on an optically rough surface; it is also a diffraction phenomenon.
- Deli meat (slices of ham or beef) appears to be iridescent, because of the diffraction off the meat fibres.
- Diffraction occurs with any kind of wave such as ocean waves diffract around jetties and other obstacles.
- Sound waves diffract around objects, that's why one can hear someone calling even when hiding behind a tree.
- The closely spaced tracks on a CD or DVD act as a diffraction grating to form the familiar rainbow pattern seen when looking at a disc.
- Its diffraction that sets a fundamental limit to the resolution of a camera, telescope or microscope.

Problem : For a single slit experiment determine how far from the central fringe the first order violet (λ = 350nm) and red (λ = 700nm) colours will appear if the screen is 10 m away and the slit is 0.050 cm wide.

Solution : We have to solve the formula for "x", the distance from the central fringe.

$$\lambda = \frac{xd}{nL} \Rightarrow x = \frac{\lambda nL}{d}$$

For the violet light $x = \frac{nL}{d}$

$$= \frac{50 \times 10^{-9} \times 1 \times 10}{0.00050} = 0.0070 \text{ m}$$

For the red light $d = \frac{00 \times 10^{-9} \times 1 \times 10}{0.00050} = 0.014$ m

- **Polarization :** A light wave that vibrates in more than one plane is referred to as unpolarized light such as the light emitted by the sun, a lamp or candle flame is unpolarized light. Such light waves consist of electromagnetic wave that vibrates in a variety of directions. However, it is possible to transform unpolarized light into polarized light.
- Polarized light waves are light waves in which the vibrations occur in a single plane. The process of transforming unpolarized light into polarized light is known as polarization. There are a variety of methods of polarizing light such as :
- **Polarization by a Polaroid filter :** These filters are made of a special material that is capable of blocking one of the two planes of vibration of, an electromagnetic wave, *i.e.* filters out one-half of the vibrations upon the transmission of the light through the filter.

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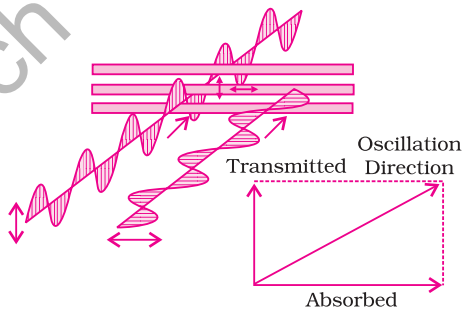
When unpolarized light is transmitted through a polaroid filter, it emerges with one-half the intensity and with vibrations in a single plane, as polarized light.

- A polaroid filter is able to polarize light because of the chemical composition of the filter material. The filter has long-chain molecules that are aligned within the filter in the same direction. A polaroid filter with its long-chain molecules aligned horizontally will have a polarization axis aligned vertically. Such a filter blocks all horizontal vibrations and allows only the vertical vibrations to be transmitted while a polaroid filter with its long-chain molecules aligned vertically will have a polarization axis aligned horizontally; it blocks all vertical vibrations and allows only the horizontal vibrations to be transmitted.
- **Polarization by Reflection :** Unpolarized light can also undergo polarization by reflection off non-metallic surfaces such as asphalt roadways, snowfields and water. They reflect light so that there is a large concentration of vibrations in a plane parallel to the reflecting surface. Someone viewing objects by light reflected off non-metallic surfaces will often perceive a glare if the extent of polarization is large. Fishermen are familiar with this glare since it prevents them from seeing fish that lie below the water.
- **Polarization by Refraction :** Polarization also occurs by the refraction of light in a plane perpendicular to the surface. The polarization of refracted light is often demonstrated by Nicol's prism or Iceland Spar, a rare form of the mineral calcite. It refracts incident light into two different paths, *i.e.* the light splits into two beams upon entering the crystal. Subsequently, if an object is viewed by looking through an Iceland Spar crystal, two images are seen. These two images are the result of the double refraction of light. Both refracted light beams are polarized.



- **Polarization by Scattering :** Polarization by scattering is observed as light passes through our atmosphere. The scattered light often produces a glare in the skies. Photographers know that this partial polarization of scattered light leads to photographs characterized by a *washed-out* sky. The problem is corrected by the use of a polaroid

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filter. As the filter is rotated, the partially polarized light is blocked and the glare is reduced. The photographic secret of capturing a clear blue sky as the backdrop of a beautiful foreground lies in the physics of polarization and polaroid filters.

- **Applications of Polarization of light in** glare-reducing sunglasses and in the entertainment industry to produce and show 3-D movies.
- **Spectrum :** It is the ordered arrangements of radiations according to wavelengths or frequencies . It can be divided in to two parts (I) Emission spectrum and (II) Absorption spectrum.
- **Emission spectrum :** When light emitted by a self-luminous object is dispersed by a prism to get the spectrum, the spectrum is called emission spectrum.

Continuous emission spectrum	Line emission spectrum	Band emission spectrum
(i) It consists of continuously varying wavelengths in a definite wavelength range.	(i) It consists of distinct bright lines.	(i) It consists of distinct bright bands.
(ii) It is produced by solids, liquids and highly compressed gases heated to high temperature.	(ii) It is produced by an excited source in atomic state.	(ii) It is produced by an excited source in molecular state.
(iii) *e.g.* Light from the sun, filament of incandescent bulb, candle flame, *etc.*	(iii) *e.g.* Spectrum of excited helium, mercury vapour, sodium vapour or atomic hydrogen.	(iii) *e.g.* Spectra of molecular H_2, *CO*, NH_3, etc.

- **Absorption spectrum :** When white light passes through a semi-transparent solid, or liquid or gas. It's spectrum contains certain dark lines or bands; such spectrum is called absorption spectrum (of the substance through which light is passed).
- Substances in atomic state produce line absorption spectra. Polyatomic substances such as H_2, CO_2 and $KNnO_4$ produces band absorption spectrum. Absorption spectra of sodium vapour have two (yellow lines) wavelengths D_1(5890 Å) and D_2 (5896 Å).
- **Fraunhoffer's lines :** The central part (photosphere) of the sun is very hot and emits all possible wavelengths of the visible light. However, the outer part (chromosphere) consists of the vapour of different elements. When the light emitted from the photosphere passes through the chromosphere, certain wavelengths are absorbed. Hence, in the spectrum of sunlight a large number of dark lines are seen which are called Fraunhoffer's lines.

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(i) The prominent lines in the yellow part of the visible spectrum were labelled as *D*-lines, those in blue part as *F*-lines and in red part as *C*-line.

(ii) From the study of Fraunhoffer's lines the presence of various elements in the sun's atmosphere can be identified, *e.g.*, abundance of hydrogen and helium.

- **Spectrometer :** A spectrometer is used for obtaining pure spectrum of a source in a laboratory and calculation of *m* of material of prism and *m* of a transparent liquid. It consists of three parts :
  - Collimator which provides a parallel beam of light
  - Prism table for holding the prism
  - Telescope for observing the spectrum and making measurements on it.
- **Direct vision spectroscope :** It is an instrument used for observing pure spectrum. It produces dispersion without deviation with the help of **n crown prisms** and **(n–1) flint prisms alternately arranged** in a tabular structure.

  For no deviation $N(\mu - 1)A = (n - 1)(\mu' - 1)A'$

Some facts about light :

- The glycerin and Pyrex rod have approximately the same refractive index. Therefore, pyrex rod in glycerin becomes invisible.
- A swimmer fails to see in deep water because the refractive index of water is almost equal to the refractive index of aqueous humour in the eye.
- Refractive index for lens immersed in water is less than that of lens in air. Hence by increasing the refractive index of the surrounding medium, a convex lens can be made to behave as a concave lens, *i.e.* a convex lens immersed in a liquid of refractive index greater than the refractive index of the lens behaves like a concave lens.
- The focal length of a mirror remains unaffected when immersed in water.
- When a convex lens is cut horizontally into two halves, its focal length remains unaffected but if cut vertically into two halves forming two plano-convex lens, the focal length also reduces by half.
- An air bubble in water behaves like a divergent lens (*i.e.* concave lens)
- A glass lens immersed in a liquid of the same refractive index disappears and does not act like a lens, *i.e.* the lens will have infinite focal length or zero focal power.
- If red light incident on a convex lens is replaced with violet light, the focal length of the lens increases.

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Chapter 16

Electrostatics

Electrostatics, laws of electrostatics, charging by friction, induction and conduction, electroscope, electric field strength, characteristics of electric lines of force, lightning, capacitor and capacitance, dielectric material and its characteristics, types of capacitors and connections.

- **Electrostatics :** It refers to the study of the charges at rest.
- **Laws of electrostatics:** There are two laws of electrostatics. The first law states that like charges of electricity repel, whereas unlike charges attract each other.
- The second law, also called Coulomb's law, states that the force exerted between two point charges
  (i) is directly proportional to the product of their magnitudes.
  (ii) is inversely proportional to the square of the distance between them, and
  (iii) is inversely proportional to the absolute permittivity of the surrounding medium.

  In equation form, Coulomb's law can be stated as

$$F = K\frac{q_1 q_2}{d^2}$$

where q_1 represents the quantity of charge on object 1 (in Coulombs), q_2 represents the quantity of charge on object 2 (in Coulombs), and d represents the distance of separation between the two objects (in metres). The symbol k is a proportionality constant known as the Coulomb's law constant. The value of this constant is dependent upon the medium that the charged objects are immersed in. In case of air, the value is approximately 9.0×10^9 N . F= c^2 /m^2.

Problem : Suppose two charges, each with a charge q = 1.00 Coulomb are separated by a distance of 1.00 metre. Determine the magnitude of the electrical force of repulsion between them.

Solution :

Given: q_1 = 1.00 C
q_2 = 1.00 C
d = 1.00 m

Find:
F_{elect} = ???

$$F_{elect} = K\frac{q_1 q_2}{d^2}$$

F_{elect} = (9.0 x 10^9 N m^2/C^2) x (1.00 C) x (1.00 C) / (1.00 m)^2
F_{elect} = 9.0 x 10^9 N

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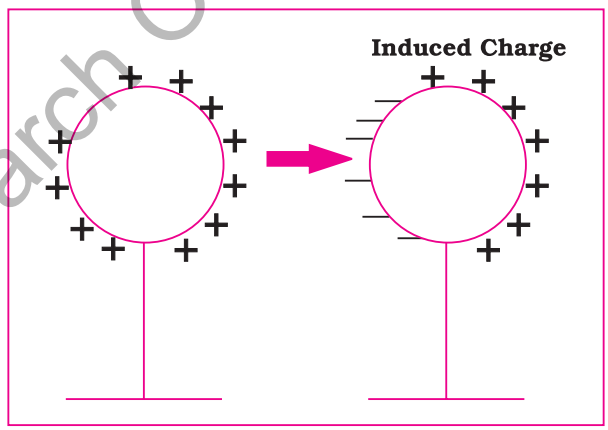
- **Electrical v/s Gravitational Forces:** Both are the two non-contact forces with the relation

  $F = K\frac{q_1q_2}{d^2}$ $\qquad$ $F = \frac{Gm_1m_2}{d^2}$

  $K = 9.0 \times 10^9\ N.m^2/C^2$ $\qquad$ $G = 6.67 \times 10^{-11}\ N.m^2/kg^2$
- The two equations have a very similar form as they show an inverse square relationship between force and separation distance. Both equations show that the force is proportional to the product of the quantity that causes the force - charge in case of electrical force and mass in case of gravitational force. Yet, there are some striking differences between these two forces.
  - firstly, the proportionality constants - K versus G - reveals that the Coulomb's law constant (k) is significantly greater than Newton's universal gravitation constant (G). Subsequently a unit of charge will attract a unit of charge with significantly more force than a unit of mass will attract another unit of mass.
  - secondly, gravitational forces are only attractive, electrical forces can be either attractive or repulsive.
- **Charging an object:** An object/a material can be charged by friction, induction or conduction.

1. **Frictional charging:** It involves the transfer of electrons between the two objects that are rubbed together. When a material deficient in electrons is rubbed with an another material having excess of electrons, it gains electrons and become negatively changed leaving the other becoming positively charged such as rubber being electron deficient become negatively charged when rubbed with animal fur leaving it to become positively charged.
2. **Charging by induction :** It is used for charging an object without actually touching the object to any other charged object.



In the proces the charged object does not transfer electrons to or receive electrons from the object being charged. The charged object merely serves to polarize the object being charged.

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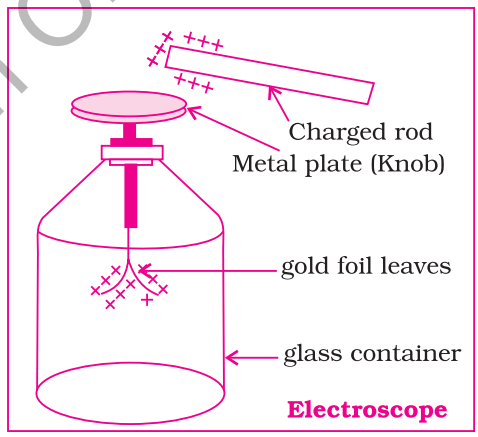
❖ The object being charged ultimately receives a charge that is opposite that of the charged object that is used to polarize it.

3. **Charging by Conduction :** It requires the presence of a conductor because it involves the touching of two conductors. Only a conductor can conduct charge to another conductor by carrying the excess charges, *i.e.* electrons to move about and redistribute themselves. An insulator hinders such a movement of electrons between touching objects. This is observed if an aluminium pie plate is placed upon a charged foam plate. When the neutral aluminium plate is placed upon the charged foam plate, the foam plate does not conduct its charge to the aluminium. Despite the fact that the two surfaces were in contact, charging by contact or conduction does not occur.

➢ **Electroscope :** It typically consists of a conducting plate or knob, a conducting base and either a pair of conducting leaves or a conducting needle. With all operating parts conducting, electrons are capable of moving from the knob on the top of the electroscope to the needle or leaves the bottom of electroscope. Objects are typically touched to or held nearby the plate or knob, thus inducing the movement of electrons into the needle or the leaves (or from the needle/leaves to the plate/knob). The gold leaves or needle of the electroscope are the only mobile parts. Once an excess of electrons (or a deficiency of electrons) is present in the needle or the gold leaves, there will be a repulsive effect between like charges causing the leaves to repel each other. Whenever this movement of the leaves/needle is observed, one can deduce that an excess of charge - either positive or negative is present there. It is important to note that the movement of the leaves and needle never directly indicate the type of charge on the electroscope; it only indicates the presence or absence of charge.



Electroscope

➢ **Electric field strength :** A charge used for measuring the electric field strength is referred to as a test charge since it is used for testing the field strength. It has a quantity of charge denoted by

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the symbol q. When placed within the electric field, it experiences an electric force - either attractive or repulsive denoted by the symbol F. The magnitude of the electric field is simply defined as the force per charge on the test charge.

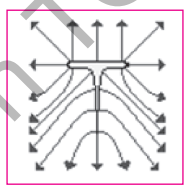
Electric field strength = Force / Charge

- If the electric field strength is denoted by the symbol E then the equation can be rewritten in symbolic form as, E = F/q.
- The standard metric units of electric field strength are Newton/ Coulomb or N/C.
- When the expression for electric force as given by Coulomb's law is substituted for force in the above E =F/q equation, a new equation can be derived as shown below:

$$E = \frac{F}{q} = \frac{k.q.Q/d^2}{q} = \frac{k.Q}{d^2}$$

$$E = \frac{k.Q}{d^2}$$

- This new formula for electric field strength expresses the field strength in terms of the two variables that affect it. The electric field strength is dependent upon
  - the quantity of charge on the source charge (**Q**)
  - distance of separation (**d**) from the source charge.
- **Characteristics of Electric Field lines:** The general characteristics as shown in the diagram are :



  - The electric field lines are directed from the positively charged thumbtack to the extremities of the page. Each field line has an arrowhead on it to indicate its directions.
  - All electric field lines should be perpendicular to the surface of the thumbtack at the locations where the lines and the thumb-tack meet.
  - There should be more lines concentrated at the pointed extremity of the thumbtack and the two sharply curved sections and fewer lines along the flatter sections of the thumbtack.
- **Lightning :** During thunderstorm as the static charge build up in a storm cloud increases, the electric field surrounding the cloud becomes stronger too. Normally, the air surrounding a cloud would be a good insulator to prevent the discharge of electrons to the Earth. Yet, the strong electric fields surrounding a cloud are capable of ionizing the surrounding air and making it more conductive. The ionization involves the shredding of electrons from the outer

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shells of gases molecules. these molecules that compose air are thus turned into a soup of positive ions and free electrons. The insulating air is transformed into a conductive **plasma**. The ability of a storm cloud's electric fields to transform air into a conductor makes charge transfer (in the form of a lightning bolt) from the cloud to the ground or even to other clouds.

- **Applications of electrostatic induction :** It is used along with the emergence of capacitor. It has come into play role for electro-mechanic precipitation or projection. In such technologies, charged particles of small sizes are collected or deposited intentionally on surfaces. Applications range from Electrostatic precipitator to Spray painting or inkjet printing. Recently developed, new Wireless Power Transfer Technology is based on electrostatic induction between oscillating distant dipoles.
- **Van de Graaff generator**: It consists of a belt of rubber running over two rollers of differing materials, one of which is surrounded by a hollow metal sphere. Two electrodes in the form of comb-shaped rows of sharp metal points, are positioned near the bottom of the lower roller and inside the sphere, over the upper roller, one comb is connected to the sphere, and other comb to ground.
- **Method of charging:** The method of charging is based on the triboelectric effect, wherein simple contact of dissimilar materials causes the transfer of some electrons from one material to the other. For example, the rubber of the belt will become negatively charged while the acrylic glass of the upper roller will become positively charged. The belt carries away negative charge on its inner surface while the upper roller accumulates positive charge. Next, the strong electric field surrounding the positive upper roller induces a very high electric field near the points of the nearby comb. At the points, the field becomes high enough to ionize air molecules, and the electrons are attracted to the out-side of the belt while positive ions go to the comb. At the comb they are neutralized by electrons that were on the comb, thus leaving the comb and the attached outer shell with fewer no. of electrons. The excess +ve charges are accumulated on the outer surface of the outer shell, leaving no field inside the shell. Electrostatic induction by this method continues, building up very large amounts of charge on the shell.

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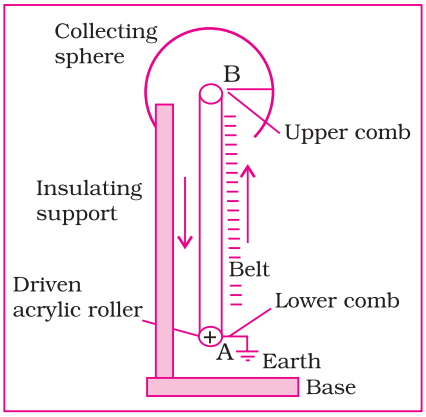

- **Van de Graaff generators and diameter :** The maximal achievable potential is approximately equal to the sphere radius R multiplied by the electric field E_{max} at which corona discharge begins to form within the surrounding gas. For air at STP the breakdown field is about 30 kV/cm. Therefore, a polished spherical electrode 30 cm in diameter could be expected to develop a maximal voltage $V_{max} = R \cdot E_{max}$ of about 450 kV. This explains why Van de Graaff generators are often made with the largest possible diameter.
- **Capacitor and capacitance :** A capacitor stores electrical charge onto its plates. The amount of electrical charge that a capacitor can store on its plates is known as its capacitance.
- **Capacitance of a capacitor :** Capacitance is the electrical property of a capacitor and is the measure of a capacitor's ability to store an electrical charge onto its two plates with the unit of capacitance being the Farad (abbreviated to F) named after the British physicist Michael Faraday. A capacitor has the capacitance of One Farad when a charge of One Coulomb is stored on the plates by a voltage of One volt. Capacitance, C is always positive and has no negative units. However, the Farad is a very large unit of measurement. Therefore sub-multiples of the Farad are generally used such as micro-farads, nano-farads and pico-farads; Microfarad (μF) $1\mu F = 10^{-6}$ F, Nanofarad (nF), $1nF = 10^{-9}$ F or Picofarad (pF) $1pF = 10^{-12}$ F
- **Factors affecting value of capacitance of a capacitor :** These include :
  - Surface Area: the surface area, A of the two conductive plates which make up the capacitor. With increasing area of plates, capacitance also increases in a capacitor.
  - Distance: the distance, d between the two plates; the smaller the distance, the greater is the capacitance.
  - Dielectric Material : the type of material which separates the two plates called the "dielectric"; the higher the permittivity of the dielectric, the greater is the capacitance.
- **Dielectric material :** It's a material that separates the metal plates of a capacitor. It can be air or even a vacuum but is generally a non-

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conducting insulating material, such as waxed paper, glass, mica different types of plastics, etc. The dielectric constant , property of the dielectric material, varies from one material to another increasing the capacitance by a factor of k. It is of importance because

- it provides mechanical support between the two plates allowing the plates to be closer together without touching.
- its permittivity increases the capacitance.
- it increases the maximum operating voltage compared to air.

- **Dielectric permittivity**: ε or dielectric constant for common materials are: Pure Vacuum = 1.0000, Air = 1.0006, Paper = 2.5 to 3.5, Glass = 3 to 10, Mica = 5 to 7, Wood = 3 to 8 and Metal Oxide Powders = 6 to 20 etc. This then gives us a final equation for the capacitance of a capacitor as :

  Capacitance, $C = \frac{\varepsilon_o \varepsilon_r A}{d}$ Farads

- Where ε_0 is the base permittivity and ε_r is relative permittivity.
- **Advantages of capacitors :** A capacitors has an insulating layer such that DC current cannot flow through it. Therefore, it is used to
  - to block DC current while passing audio signals, pulses, or alternating current, or other time varying wave forms. This ability to block DC currents enables capacitors to be used for smoothening the output voltages of power supplies.

  - to adjust the frequency response of an audio circuit, or coupling together separate amplifier stages that must be protected from the transmission of DC current.
- **Working characteristics of a capacitor :** At DC, a capacitor has infinite impedance (open-circuit), at very high frequencies a capacitor has zero impedance (short-circuit). All capacitors have a maximum working voltage rating, its WV DC. So selecting a capacitor with a rating at least 50% more than the supply voltage is significant.
- A parallel plate capacitor is the simplest form of a capacitor. It can be constructed using two metal or metallised foil plates at a distance parallel to each other, with its capacitance value in Farads, being fixed by the surface area of the conductive plates and the distance of separation between them.

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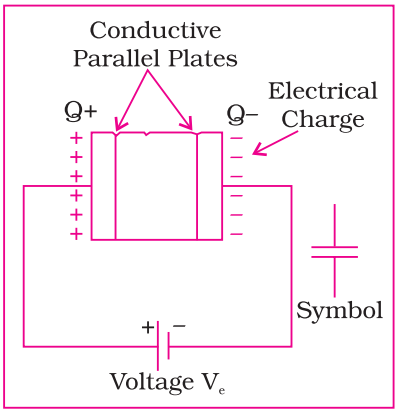


Combination of capacitors :

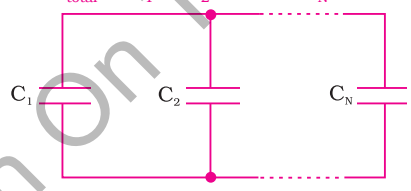
Series – connected capacitors:

$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N} \text{ [F]}$$

- Total capacitance of series-connected capacitors is equal to the reciprocal of the sum of the reciprocals of the individual capacitances.

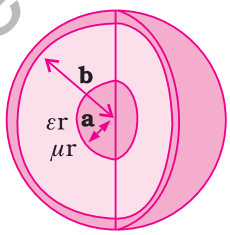
Parallel – connected capacitors

$$C_{total} = C_1 + C_2 + ... + C_N \text{ [F]}$$



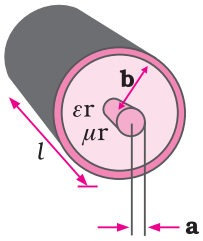
- Total capacitance of parallel-connected capacitors is equal to the sum of the individual capacitances.

Concentric Sphere capacitance



$$c = \frac{4.\pi.\varepsilon_o.\varepsilon_r}{\frac{1}{a} - \frac{1}{b}} [m,F]$$

Coxial Cable capacitance



$$c = \frac{2.\pi.\varepsilon_o.\varepsilon_r.l}{ln(\frac{b}{a})} [m,F]$$

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- **Capacitive Reactance,** (X_C, in Ω) It is inversely proportional to the frequency (ω, in radians/sec, or f, in Hz) and capacitance (C, in Farads). Pure capacitance has a phase angle of -90° (voltage lags current with a phase angle of 90°).
- **Charge Stored on a Capacitor :** Q = C. V [F, V]

  Charge (Q, in Coulombs) on the plates of a capacitor is the product of the capacitance (C, in Farads) and the voltage (V, in volts) across the device.
- **Energy Stored in a Capacitor :** $W = \frac{1}{2}.C.\ V^2\ [F,V,J]$

  Energy (W, in Joules) stored in a capacitor is half the product of the capacitance (C, in Farads) and the voltage (V, in volts) across the device.
- **Current through a Capacitor :** $i_c(t) = C\ \frac{dv}{at}[F,A]$

  Current does actually flow 'through' an ideal capacitor. Rather, charge stored on its plates is given up to the connected circuit, thereby facilitating current flow. Conversely, a net voltage applied to its plates causes a current to flow in the connected circuit as charge accumulates on the plates.
- **Quality Factor of a Capacitor :** $i_c(t) = C\ \frac{dv}{at}[F,A]$

  Quality factor is the dimensionless ratio of reactance to resistance in a capacitor.

  Problem : Given a parallel plate-capacitor of 1200 μF in vacuum. If the area of capacitor plates is doubled and the separation between two plates is 1.5 times the original, find the new capacitance of the capacitor.

  Solution : we know

$$C = \frac{kAe_o}{d}$$

$$\frac{C_2}{C_1} = \frac{A_2}{A_1} \times \frac{d_1}{d_2}$$

$$\frac{C2}{1200} = \frac{(2)\ (1)}{(1)\ (1,5)}$$

$$C_2 = \frac{2}{1,5} \times = 1200 = 1600\ \mu F$$

  Problem : Given a parallel-plate capacitor in vacuum. The plates of capacitor are 2 cm apart and 50 cm² in area of each plate. A potential difference of 120 volts is applied across the capacitor. When ε_o is 8.85 ×10^{-12} Nm²c^{-2} calculate :

  (a) capacitor's capacitance

  (b) charge stored in capacitor

  (c) the magnitude of electric charge in space between the two plates of capacitor

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Solution : (a) Capacitance of the capacitor

$$C = \frac{kAe_o}{d}$$

$$C = \frac{(1)\ (50 \times 10^{-4})\ (8{,}85 \times 10^{-12})}{2 \times 10^{-2}} = 2{,}2 \times 10^{-12} = 2{,}2\ pF$$

(b) Charge stored in capacitor

$Q = CV$

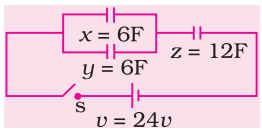
$Q = (2.2 \times 10^{-12})\ (120) = 264 \times 10^{-12} = 264\ pC$

(c) The magnitude of electric charge in space between the two plates of capacitor

$$E = \frac{V}{d}$$

$$E = \frac{120}{2 \times 10^{-2}} = 600\ v/m$$

Problem : In the circuit given below, there is a combination of three capacitors X, Y and Z.



If the switch S is ON, find:

(a) circuit equivalent capacitance (equivalent capacitor)
(b) electric charge stored in the circuit
(c) electric charge stored in capacitor Z, (use series principle)
(d) potential difference across capacitor Z
(e) potential difference across capacitor X
(f) potential difference across capacitor Y
(g) electric charge stored in capacitor X
(h) electric charge stored in capacitor Y
(i) electric charge stored in capacitor Z
(j) energy stored in the circuit
(k) energy stored in capacitor X
(l) energy stored in capacitor Y
(m) energy stored in capacitor Z

Solution : (a) First, replace X and Y parallel combination by its equivalent capacitance, named C_{xy} :

$C_{xy} = C_x + C_y$

$C_{xy} = 6 + 6 = 12$ F

Replacing the two capacitors gives us the equivalent circuit in series combination, then find the equivalent for C_{xy} and C_z, the two are in series, called C_{eq} or C_{tot} :

$$\frac{1}{C_{tot}} = \frac{1}{C_{xy}} + \frac{1}{C_z}$$

$$\frac{1}{C_{tot}} = \frac{1}{12} + \frac{1}{12} = \frac{2}{12}$$

$$\frac{1}{C_{tot}} = \frac{12}{2} = 6F$$

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(sb) Charge stored in the circuit or the charge in the equivalent capacitance: Q_{tot} , C_{tot} multipled by V_{tot}

$$Q_{tot} = C_{tot} V_{tot} = 6(24) = 144 \text{ C}$$

(c) Charge stored in capacitor Z; Q_z

For series combination, the charge is the same on all capacitors. It's the same as the charge on the equivalent capacitor :

$$Q_{xy} = Q_Z = Q_{tot}$$
$$Q_Z = 144 \text{ C}$$

(d) Potential difference across capacitor Z, named V_z

$$V_z = \frac{Q_z}{C_z} = \frac{144}{12} = 12 \text{ Volts}$$

(e) Potential difference across capacitors X and Z are the same cause of parallel combination

$$V_x = V_{xy} = \frac{Q_{xy}}{C_{xy}} = \frac{144}{12} = 12 \text{ Volts}$$

(f) Potential difference across Y is the same as potential difference across X

$$V_y = V_x = 12 \text{ Volts}$$

(g) Charge in capacitor X : It's not the same as charge in equivalent capacitor

$$Q_x = C_x V_x = 6(12) = 72\text{C}$$

(h) Charge in capacitor Y

$$Q_y = C_y V_y = 6(12) = 72 \text{ C}$$

(i) Charge in capacitor Z

$$Q_z = C_z V_z = 12(12) = 144 \text{ C}$$

(j) Energy stored in the circuit

Use one of these three formulas to get the energy stored

$$W = \frac{1}{2}VB^2$$

$$W = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}Q.\frac{Q}{C}\left[\frac{Q}{C} = V\right]$$

$$W = \frac{1}{2}QV$$

So then, $W_{tot} = \frac{1}{2} CV^2 = \frac{1}{2} (6) (24)^2 = 1728$ J

(k) Energy stored in capacitor X

$$W_x = \frac{1}{2} C_x V_x^2 = \frac{1}{2}(6)(12)2 = 432 \text{ J}$$

(l) Energy stored in capacitor Y

$$W_y = \frac{1}{2} C_y V^2_Y = \frac{1}{2} (6) (12)^2 = 432 \text{ J}$$

(m) Energy stored in capacitor Z

$$W_z = \frac{1}{2} C_z V^2_z = \frac{1}{2} (12) (12)^2 = 864 \text{ J}$$

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Chapter 17

CURRENT ELECTRICITY

PHYSICS

Electrical potential, potential difference, Ohm's law, resistance, restivity, electric circuit-series and parallel circuit, RLC circuits, series resonance circuit.

- **Electric potential :** It is defined as the potential energy per charge.

$$\text{Electric Potential} = \frac{PE}{Q}$$

- Electric potential is used to express the effect of an electric field of a source in terms of the location within the electric field. A test charge with twice the quantity of charge would posses twice the potential energy at a given location, yet, its electric potential at that location would be the same as any other test charge. A positive test charge would be at a high electric potential when held close to a positive source charge and at a lower electric potential when held farther away.
- The negative terminal is described as the low potential terminal. This assignment of high and low potential to the terminals of an electrochemical cell presumes the traditional convention that electric fields are based on the direction of the movement of positive test charges.
- **Electric potential difference :** It is defined as the difference in electric potential (V) between the final and the initial location when work is done upon a charge to change its potential energy. In equation form, the electric potential difference is

$$\Delta V = V_B - V_A = \frac{\text{Work}}{\text{Charge}} = \frac{\Delta PE}{Q}$$

- The standard metric unit on electric potential difference is the volt, abbreviated V and named in honour of Alessandro Volta. One Volt is equivalent to one Joule per Coulomb. If the electric potential difference between two locations is 1 volt, then one Coulomb of charge will gain 1 joule of potential energy when moved between those two locations. If the electric potential difference between two locations is 3 volts, then one coulomb of charge will gain 3 joules of potential energy when moved between those two locations.

  Two simple circuits and their corresponding electric potential diagrams are shown below. In Circuit A, there is a 1.5-volt D-cell and a single light bulb. In Circuit B, there is a 6-volt battery (four 1.5-volt D-cells) and two light bulbs. In each case, the negative terminal of the battery is the 0 volt location.

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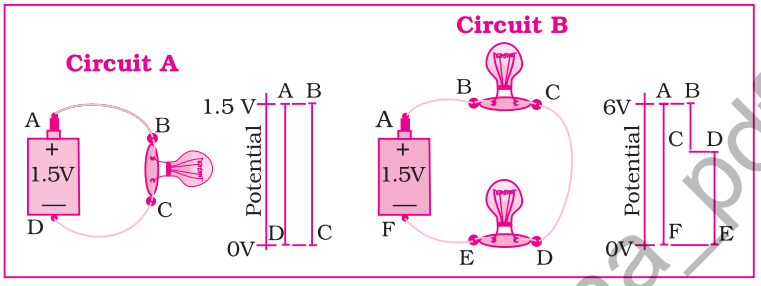
- The positive terminal of the battery has an electric potential that is equal to the voltage rating of the battery. The battery energizes the charge to pump it from the low voltage terminal to the high voltage terminal. By doing so the battery establishes an electric potential difference across the two ends of the external circuit.



- **Requirements to establish an electric circuit :** There are two primary requirements to establish an electric circuit. These requirements are:
  - There must be an energy supply capable of doing work on charge to move it from a low-energy location to a high-energy location to establish an electric potential difference across the two ends of the external circuit.
  - There must be a closed conducting loop in the external circuit that stretches from the high potential, positive terminal to the low potential, negative terminal.
- **Drift velocity :** It refers to the average distance travelled by a charge carrier per unit time. The drift speed of an electron moving through a wire is the distance to time ratio. The path of a typical electron through a wire is chaotic, zigzag path characterized by collisions with fixed atoms. Each collision results a change in the direction of the electron. Yet because of collisions with atoms in the solid network of the metal conductor, there are two steps backwards for every three steps forward. With an electric potential established across the two ends of the circuit, the electron continues to migrate forward towards the positive terminal. The overall effect of the countless collisions and the high collision speeds is that the overall drift speed of an electron in a circuit is abnormally low. A typical drift speed might be 1 metre per hour.

Typical Path of an Electron

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- **Electric current :** Current is the rate at which charges flow past a point on a circuit. The current in a circuit can be determined if the quantity of charge Q passing through a cross section of a wire in a time *t* can be measured. The current is simply the ratio of the quantity of charge and time.

$$\text{Current} = I = \frac{Q}{t}$$

- The standard metric unit for current is the ampere. Ampere is often shortened to Amp and is abbreviated by the unit symbol A. A current of 1 ampere means that there is 1 coulomb of charge passing through a cross section of a wire every 1 second.

  1 ampere = 1 coulomb / one second

- **Ohm's law :** According to this, law, the current in a circuit is directly proportional to the electric potential difference impressed across its ends at given temperature, *i.e.* $V \propto I$ or $V = IR$

  Where R is the total resistance offered by the external circuit.

- **Resistance :** It is the hindrance to the flow of charge. In an electric circuit, the electric potential difference established between the two terminals encourages the movement of charge but it is resistance that discourages it. The rate at which charge flows from terminal to terminal is the result of the combined effect of these two quantities.

- **Factors affecting Electrical Resistance :** The total amount of resistance to charge flow within a wire or conductor of an electric circuit is affected by a number of variables such as the:
  - total length of the wires, with increasing length, the resistance increases too.
  - cross-sectional area of the wires will affect the amount of resistance. The wider the wire, the less resistance there is to the flow of electric charge. When all other variables are the same, charge will flow at higher rates through wider wires with greater cross-sectional area than through thinner wires.
  - the material that a wire is made of. Some materials with low resistivity are better conductors than others, *i.e.* offer less resistance to the flow of charge. Silver is one of the best conductors but copper and aluminium being cheaper with suitable conducting ability are used in wires of household circuits, lead is the poor conductor.

- The equation representing the dependency of the resistance (R) of conductor (e.g., a wire) upon the variables that affect it is

$$R = \rho \frac{L}{A}$$

  where L represents the length of the wire (in metres), A represents the cross-sectional area of the wire (in metres^2), and ρ (roh) represents the resistivity of the material (in ohm/meter).

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- **Resistivity :** It refers to the conducting ability of a material. The resistivity of a material is dependent upon the electronic structure of the material and its temperature. For most (but not all) materials, resistivity increases with increasing temperature. The materials with lower resistivities offer less resistance to the flow of charge they are better conductors. The materials with high resistivity are not considered to be conductors.
- **Joule's law of heating :** Joule had proposed both the law of cooling and heating. According to Joules law of heating with respect to electric current passing through a resistor is proportional to the value of the current squared resistance and time.

$$H = I^2Rt$$

When it is the heat produced in Joule's I is the current, R is the resistance and t is the time, the current has been passed through the resistor.

Quantity	Symbol	Equation(s)	Standard Metric Unit	Other Units
Potential Difference (or voltage)	ΔV	ΔV = ΔPE/Q ΔV = I x R	Volt (V)	J / C
Current	I	I = Q/t	Amperes (A)	Amp or C/s or V/Ω
Power	P	P = ΔPE/t	Watt (W)	J / s
Resistance	R	R = ρ x L / A R = ΔV / I	Ohm (Ω)	V / A
Energy	E or ΔPE	ΔPE = ΔV x Q ΔPE = P • t	Joule (J)	V • C or W • s

Mechanical System	Electrical System
Mass (m)	Inductance L
Force Constant k	Reciprocal Capacitance
Displacement x	Charge q
Velocity $v = dx/dt$	Current $i = dq/dt$
Mechanical Energy	Electromagnetic energy
$E = \frac{1}{2}kx^2 = \frac{1}{2}mv^2$	$U = \frac{1}{2}\frac{q^2}{c} = \frac{1}{2}Li^2$

- **Some common circuit symbols :** Some circuit symbols used in schematic diagrams are shown below.

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- **Equivalent resistance :** It is the resistance of a circuit, that is the amount a single resistor would need in order to equal the overall effect of the collection of resistors that are present in the circuit. For series circuits, the mathematical formula for computing the equivalent resistance (R_{eq}) is

  $R_{eq} = R_1 + R_2 + R_3 + \ldots$

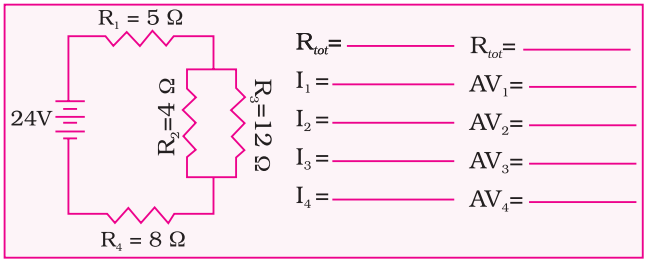
  where R_1, R_2, and R_3 are the resistance values of the individual resistors that are connected in series.
- For parallel circuits, the mathematical formula for computing the equivalent resistance (R_{eq}) is $1 / R_{eq} = 1/R_1 + 1/R_2 + 1 / R_3 + \ldots$

  where R_1, R_2, and R_3 are the resistance values of the individual resistors that are connected in parallel.

Series circuit v/s Parallel circuit:

Series Circuit	Parallel Circuit
The current is the same in every resistor; thus current is equal to that in the battery.	The sum of the current in each individual branch is equal to the current outside the branches.
The sum of the voltage drops across the individual resistors is equal to the voltage rating of the battery.	The voltage drop is the same across each parallel branch.
The overall resistance of the collection of resistors is equal to the sum of the individual resistance values. $R_{tot} = R_1 + R_2 + R_3 + \ldots$	The equivalent or overall resistance of the collection of resistors is given by the equation : $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 \ldots$

- **Problem :** Determine the current in and the voltage drop across each resistor.



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Solution : The equivalent resistance of a 4-Ω and 12-Ω resistor placed in parallel

$1 / R_{eq} = 1 / R_1 + 1 / R_2 + 1 / R_3 \ldots$

$1 / R_{eq} = 1 / (4\ \Omega) + 1 / (12\ \Omega)$

$1 / R_{eq} = 0.333\ \Omega^{-1}$

$R_{eq} = 1 / (0.333\ \Omega^{-1})$

$R_{eq} = 3.00\ \Omega$

- The two branch resistors (R_2 and R_3) can be replaced by a single resistor with a resistance of 3 Ω. This 3 Ω resistor is in series with R_1 and R_4. Hence, the total resistance is

$R_{tot} = R_1 + 3\ \Omega + R_4 = 5\ \Omega + 3\ \Omega + 8\ \Omega$

$R_{tot} = 16\ \Omega$

Using Ohm's law equation, $\Delta V = I \times R$

$I_{tot} = \Delta V_{tot} / R_{tot} = (24\ V) / (16\ \Omega)$

$I_{tot} = 1.5$ Amp

$I_{tot} = I_1 = I_4 = 1.5$ Amp

The voltage drop across each resistor

$\Delta V_1 = I_1 \times R_1 = (1.5\ Amp) \times (5\ \Omega) = 7.5\ V$

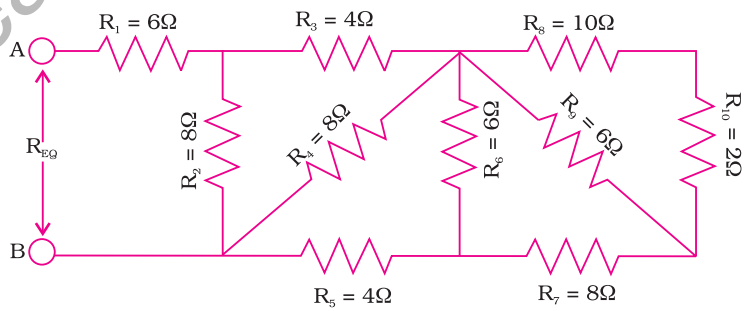
$\Delta V_4 = I_4 \times R_4 = (1.5\ Amp) \times (8\ \Omega) = 12\ V$

- This circuit is powered by a 24-volt source. Thus, the cumulative voltage drop of a charge traversing a loop about the circuit is 24 volts. There will be a 19.5 V drop (7.5 V + 12 V) resulting from passage through the two series-connected resistors (R_1 and R_4). The voltage drop across the branches must be 4.5 volts to make up the difference between the 24-volt total and the 19.5-volt drop across R_1 and R_4. Thus, Ä$V_2 = V_3 = 4.5$ V, the current in the two branches.

$I_2 = \Delta V_2 / R_2 = (4.5\ V) / (4\ \Omega) = 1.125\ A$

$I_3 = \Delta V_3 / R_3 = (4.5\ V) / (12\ \Omega) = 0.375\ A$

Problem : Find the equivalent resistance, R_{EQ} for the following resistor combination circuit.



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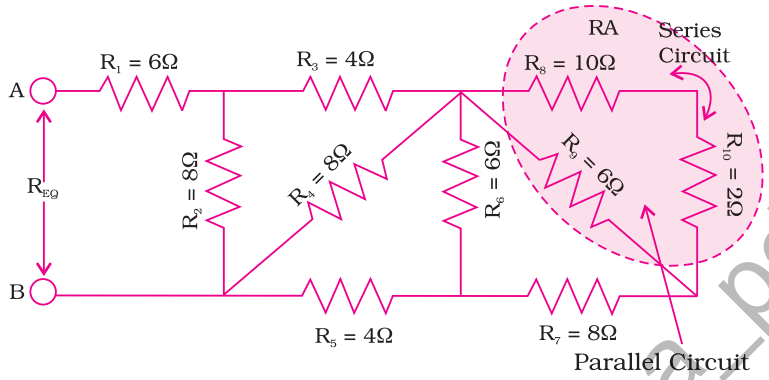
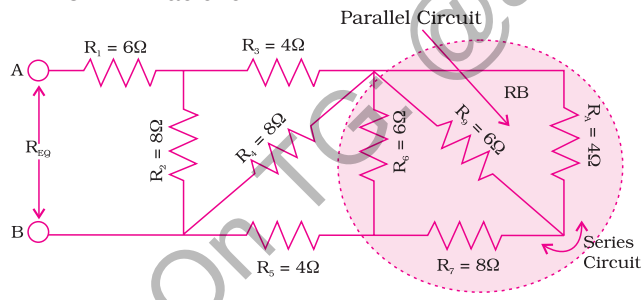
Solution : First we can find the equivalent resistance of R_8 to R_{10} combination and call it R_A.



$$R_A = \frac{R_9 (R_8 + R_{10})}{R_9 + R_8 + R_{10}} = \frac{6 \times (10 + 2)}{6 + 10 + 2} = 4\Omega$$

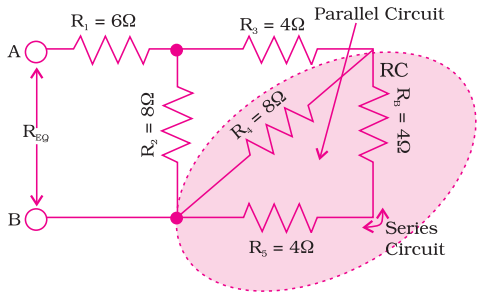
R_A is in series with R_7; therefore, the total resistance will be $R_A + R_7 = 4 + 8 = 12\Omega$ as shown.



This resistive value of 12Ω is now in parallel with R_6 and can be calculated as R_B.

$$R_B = \frac{R_6 \times (R_A + R_7)}{R_6 + R_A + R_7} = \frac{6 \times (4 + 8)}{6 + 4 + 8} = 4\Omega$$

R_B is in series with R_5; therefore, the total resistance will be $R_B + R_5 = 4 + 4 = 8\Omega$ as shown.



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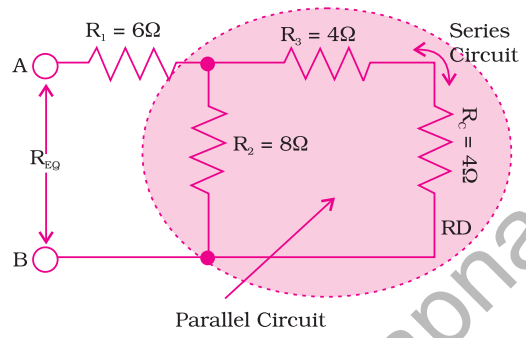
This resistive value of 8Ω is now in parallel with R_4 and can be calculated as R_C as shown.

$$R_C = \frac{R_4 \times (R_B + R_5)}{R_4 + R_B + R_5} = \frac{8 \times (4 + 4)}{8 + 4 + 4} = 4\Omega$$

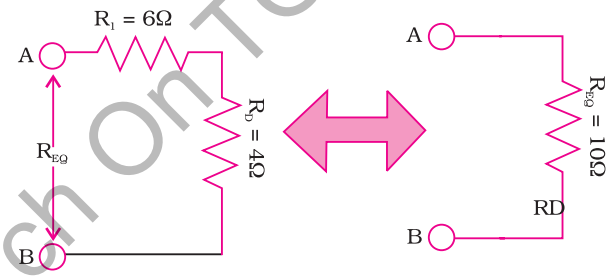
R_C is in series with R_3; therefore, the total resistance will be $R_C + R_3 = 8\Omega$ as shown.



This resistive value of 8Ω is now in parallel with R_2 from which we can calculate R_D as:

$$R_D = \frac{R_2 \times (R_C + R_3)}{R_2 + R_C + R_3} = \frac{8 \times (4 + 4)}{8 + 4 + 4} = 4\Omega$$

R_D is in series with R_1; therefore, the total resistance will be $R_D + R_1 = 4 + 6 = 10\Omega$ as shown.



- Then the complex combinational resistive network above comprising ten individual resistors connected together in series and parallel combinations can be replaced with just one single equivalent resistance (R_{EQ}) of value 10Ω.
- **Series Resonance Circuit :** In a series RLC circuit, there becomes a frequency point where the inductive reactance of the inductor becomes equal in value to the capacitive reactance of the capacitor, i.e. $X_L = X_C$. The point at which this occurs is called the Resonant Frequency point, (f_r) of the circuit.
- *Series Resonance* circuits are used in electrical and electronic circuits. They can be found in various forms such as in AC mains filters, noise filters and also in radio and television tuning circuits

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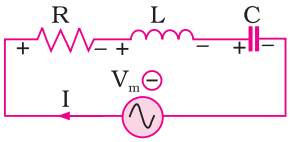
producing a very selective tuning circuit for the receiving of the different frequency channels. Consider the simple series RLC circuit below.

Series RLC Circuit :

Inductive reactance : $X_L = 2\pi fL = \omega L$

Capacitive reactance = $\frac{1}{2\pi fC} = \frac{1}{\omega C}$



When $X_L > X_C$, the circuit is inductive.

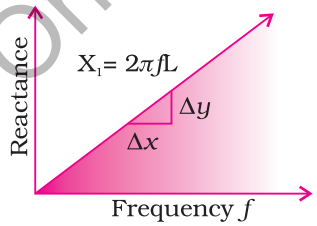
When $X_L < X_C$, the circuit is capacitive.

Total circuit reactance = $X_T = X_L - X_C$ or $X_C - X_L$

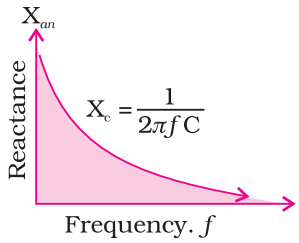
Total circuit impedance = $Z = X_L R^2 + X_T^2 = R + jX$

- From the above equation for inductive reactance, if either the Frequency or the Inductance is increased, the overall inductive reactance value of the inductor would also increase.
- However, as the frequency approaches zero or DC, the reactance of the inductors would decrease to zero, causing the opposite effect to act like a short circuit, *i.e.* inductive reactance is proportional to frequency and is small at low frequencies and high at higher frequencies.

Inductive Reactance against Frequency



Capacitive Reactance against Frequency



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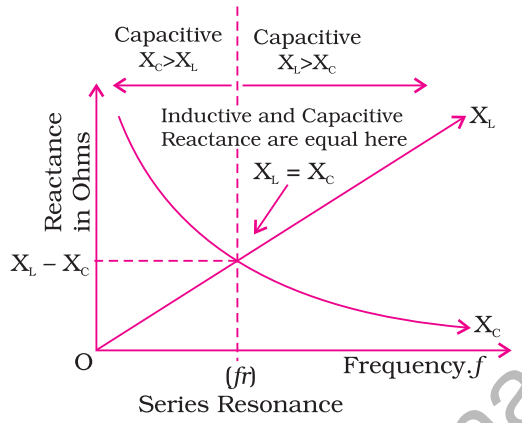
Series Resonance Frequency :



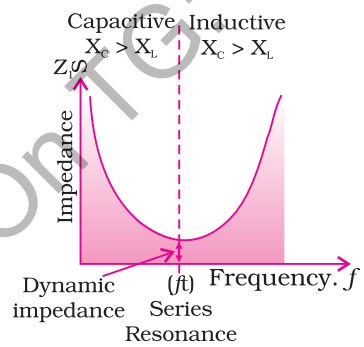
$X_L = X_C \Rightarrow 2\pi f L = 1/2\pi f C$

$f^2 = 1/2\pi L \times 2\pi C = 1/4\pi^2 LC$

or $f_r = 1/2\pi\sqrt{LC}$ (Hz) or $w_r = 1/\sqrt{LC}$ (rad)

- Then at resonance the impedance of the series circuit is at its minimum value and equal only to the resistance, R of the circuit.

Impedance in a Series Resonance Circuit



- In series RLC circuits that the voltage across a series combination is the phasor sum of V_R, V_L and V_C. Then if at resonance the two reactances are equal and cancelling, the two voltages representing V_L and V_C must also be opposite and equal in value thereby cancelling each other out because with pure components the phasor voltages are at +90° and -90° respectively.
- Then in a series resonance circuit as $V_L = -V_C$ the resulting reactive voltages are zero and all the supply voltage is dropped across the resistor. Therefore, $V_R = V_{supply}$ and it is for this reason that series resonance circuits are known as voltage resonance circuits, (as opposed to parallel resonance circuits which are current resonance circuits).

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Chapter 18

Electrical Measurements And Used Devices

Electrical measurements, list of standard electrical units, list of electrical and electronic measuring instruments, different types of measuring instruments, Kirchhoff's laws, Wheatstone bridge and measurement, moving coil galvanometer, conversion of galvanometer into ammeter and voltmeter, ammeter v/s voltmeter, potentiometer and measurement of emf of a cell.

➢ **Electrical measurements :** These measurements often come down to either measuring current or measuring voltage. Even if someone measures frequency, he will be measuring the frequency of a current signal or a voltage signal and for this, he needs to know how to measure either voltage or current.

Standard Electrical Units

Electrical parameter	Unit	Symbol	Description
Voltage	Volt	V or E	$V = I \times R$
Current	Ampere	I or i	$I = V \div R$
Resistance	Ohm	R or Ω	$R = V \div I$
Conductance	Siemen or Mho	G or ℧	$G = 1 \div R$
Capacitance	Farad	C	$C = Q \div V$
Charge	Coulomb	Q	$Q = C \times V$
Inductance	Henry	L or H	$V_L = -L(di/dt)$
Power	Watt	W	$P = V \times I$ or $I^2 \times R$
Impedance	Ohm	Z	$Z^2 = R^2 + X^2$
Frequency	Hertz	Hz	$f = 1 \div T$

List of measuring instruments used in electrical and electronic work

Name	Purpose
Ammeter (Amperemeter)	Measures current
Capacitance meter	Measures the capacitance of a component
Cos Phi Meter	Measures the power factor
Electricity meter	Measures the amount of energy dissipated
ESR meter	Measures the equivalent series resistance of capacitors
Frequency counter	Measures the frequency of the current

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LCR meter	Measures the inductance, capacitance and resistance of a component
Multimeter	A general purpose instrument measures voltage, current and resistance (and sometimes other quantities as well)
Ohmmeter	Measures the resistance of a component
Oscilloscope	Displays the waveform of a signal
Q meter	Measures Q factor of the RF circuits
Signal analyzer	Measures both the amplitude and the modulation of a RF signal
Signal generator	Generates signals for testing purposes
Spectrum analyser	Displays frequency spectrum
Transistor tester	Tests transistors
Tube tester	Tests vacuum tubes (triode, tetrode, etc.)
Wattmeter	Measures the power
Voltmeter	Measures potential difference between two points in a circuit.
VU meter	Measures the level of AF signals in volume units

Classification of measuring Instruments : The different classes of measuring instruments include :

- **Mechanical instruments :** They are very reliable for static and stable conditions. The disadvantage is that they are unable to respond rapidly to the measurement of dynamic and transient conditions.
- **Electrical instruments :** Electrical methods of indicating the output of detectors are more rapid than mechanical methods. The electrical system normally depends upon a mechanical meter movement as indicated on device.
- **Electronic instruments :** These instruments have very fast response. For example, a cathode ray oscilloscope (CRO) is capable of following dynamic and transient changes of the order of a few nano seconds (10^{-9} sec).
- **Absolute Instruments or Primary Instruments :** These instruments give the magnitude of quantity under measurement in terms of physical constants of the instrument .These instruments do not require comparison with any other standard instrument. These instruments give the value of the electrical quantity in terms of absolute quantities (or some constants) of the instruments and their deflections. Some of the examples of absolute instruments are Tangent galvanometer and Absolute electrometer.
- **Secondary instruments :** These are the most commonly used instruments which are so constructed that the quantity being measured can only be determined by the output indicated by the

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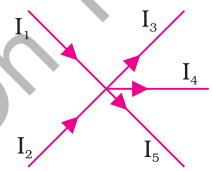
instruments. These instruments are calibrated by comparison with an absolute instrument or another secondary instrument, which has already been calibrated against an absolute instrument. Some of these instruments are: ammeter, voltmeter, wattmeter, energy meter (watt-hour meter), ampere-hour meter, etc.

- These instruments based on various effects of electric current (or voltage) upon which their operation depend are of different types:
  - **Magnetic effect :** Used in ammeters, voltmeters, watt-meters, etc.
  - **Heating effect :** Used in ammeters and voltmeters.
  - **Chemical effect :** Used in dc ampere hour meters.
  - **Electrostatic effect :** Used in voltmeters.
  - **Electromagnetic induction effect :** Used in ac ammeters, voltmeters, watt meters and integrating meters.

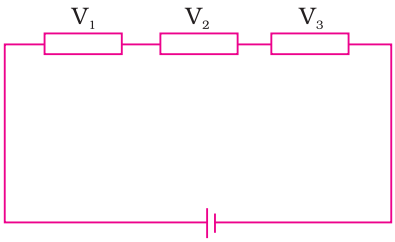
Classification based on the method used for measurement :

- **Direct measuring instruments :** These instruments convert the energy of the measured quantity directly into energy that actuates the instrument and the value of the unknown quantity is measured or displayed or recorded directly. These instruments are most widely used because time involved in the measurement is the shortest possible. Examples are Ammeter, Voltmeter, Watt meter, etc.
- **Comparison instruments :** These instruments measure the unknown quantity by comparison with a standard. Examples are dc and ac bridges and potentiometers. They are used when a higher accuracy of measurements is desired.



$I_1 + I_2 = I_3 + I_4 + I_5$

- **Kirchhoff's laws :** Guatov Robert Kirchhoff proposed two laws to determine equivalent electrical resistance or impedance (in case of AC) of a complex network and the currents flowing in the various branches of the network.



$V = V_1 + V_2 + V_3$

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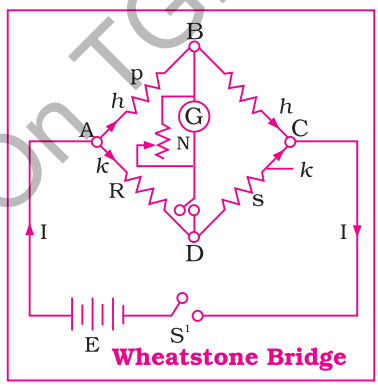
- **Kirchhoff's First Law :** It states that, at any junction point in the electrical circuit, the summation of all the branch currents is zero. If we consider, all the currents entered in the junction are considered as positive current, then the convention of all the branch currents leaving the junction is negative. Now if we add all these positive and negative signed currents, we get the result of zero. The mathematical form of Kirchhoff's First Law is $\Sigma I = 0$ at any junction of electrical network.
- **Kirchhoff's Second Law :** It states that net voltage gain and net voltage drops along a closed loop are equal, *i.e.* according to Kirchhoff's Second Law, $\Sigma V = 0$.
- **Wheatstone Bridge :** It is used for measuring accurately any electrical resistance. It consists of two known resistors, one variable resistor and one unknown resistor connected in bridge as shown in the figure. By adjusting the variable resistor, the current through the galvanometer is made zero. When the current through the galvanometer becomes zero, the ratio of two known resistors is exactly equal to ratio of the adjusted value of variable resistance and the value of unknown resistance. Hence, the value of unknown electrical resistance can easily be measured using a Wheatstone bridge, *i.e.* P/Q = R/S



Wheatstone Bridge

Problem : The following unbalanced Wheatstone Bridge is constructed. Calculate the output voltage across points C and D and the value of resistor R4required to balance the bridge circuit.

Solution : For the first series arm, ACB

$$V_C = \frac{R_2}{(R_1 + R_2)} \times V_s$$

$$Vc = \frac{120\Omega}{80\Omega + 120\Omega} \times 100$$

$$= 60 \text{ V}$$

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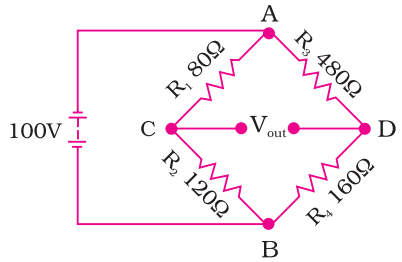
For the second series arm, ADB



$$V_D = \frac{R_4}{(R_3 + R_4)} \times V_s$$

$$V_D = \frac{160\Omega}{480\Omega + 160\Omega} \times 100$$

$$= 25 \text{ V}$$

The voltage across points C-D is given as:

$V_{OUT} = V_C - V_D$

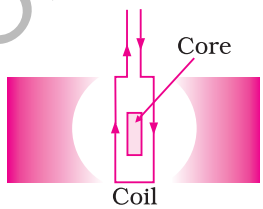
$\therefore \quad V_{OUT} = 60 - 25 = 35$ Volts

The value of resistor, R_4 required to balance the bridge is given as:

$$R_4 = \frac{R_2R_3}{R_1} = \frac{120\Omega \times 480\Omega}{80\Omega} = 720\ \Omega$$

- **Moving coil galvanometer :** It consists of a rectangular coil placed in a uniform magnetic field produced by cylindrical pole pieces to make the magnetic field radial.

  Torque on coil τ = *NIAB* where *N* is number of turns, *A* is area of coil.



- If *C* is torsional rigidity of material of suspension wire, then for deflection θ, torque $\tau = C\,\theta$

  $\therefore$ For equlibrium NIAB = Cθ

$$\theta = \frac{NAB}{C} I$$

Clearly deflection in galvanometer is directly proportional to current, so the scale of galvanometer is linear.

Sensitivity of galvanometer :

- **Current sensitivity :** It is defined as the deflection of coil per unit current flowing through it.

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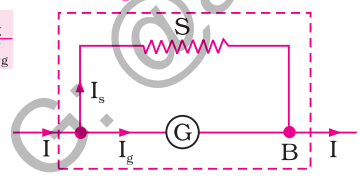
Sensitivity $S_I = \left(\frac{\theta}{I}\right) = \frac{NAB}{C}$

i.e., $SV = \frac{\theta}{V} = \frac{NAB}{GC}$

Where G is the resistance of galvanometer.

- **Voltage sensitivity :** It is defined as the deflection of coil per unit potential difference across its ends where *G* is the resistance of galvanometer.
- Clearly, for the greater sensitivity number of turns *N*, area *A* and magnetic field strength *B* should be large and torsional rigidity *C* of suspension should be small.
- **Ammeter :** It is a low resistance galvanometer and is connected in series in a circuit to read current directly in '*A*'. The resistance of an ammeter is to be made as low as possible so that it may read current without any appreciable error. Therefore to convert a galvanometer into ammeter a shunt resistance. (i.e. small resistance in parallel) is connected across the coil of the galvanometer.

Shunt required, $S = \frac{GI_g}{I - I_g}$

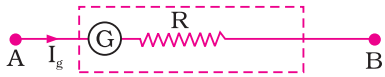


Ammeter

- This is the working equation for the conversion of a galvanometer into an ammeter. The resistance of an ammeter so formed is

$$R_A = \frac{SG}{S + G}$$

- The *k is the figure of* merit of the galvanometer and *n* is the number of scale divisions, then $I_g = nk$. Out of the total main current amperes, only a small permissible value I_g flows through the galvanometer and the rest $I_s = (I - I_g)$ passes through the shunt. An ideal ammeter has zero resistance.
- **Voltmeter :** It is a high resistance galvanometer and is connected in parallel to the element across which the potential difference is to be determined. The resistance of a voltmeter is made as high as possible, so that it may read voltage without any appreciable error. Therefore to convert a galvanometer into a voltmeter, a high resistance is connected in series with the galvanometer.



Voltmeter

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$I_g = \frac{V}{R + G}$ $R = \frac{V}{I_g} - G$

- This is working equation of the conversion of a galvanometer into a voltmeter. The resistance of a voltmeter so formed is $R_V = G + R$.
- If V_0 is initial voltage across the galvanometer when a current I_g passes through it, then $I_g = \frac{V}{I_g}$.
- If *k* is figure of the merit of the galvanometer and *n* the number of scale divisions, then $I_g = nk$. An ideal voltmeter has infinite resistance.

Ammeter v/s Voltmeter

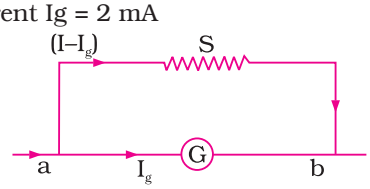
Character	Ammeter	Voltmeter
Connection	It is to be connected in series mode.	It is to be connected in parallel mode.
Resistance	It has low resistance.	It has high resistance.
Uses	It is used for finding the current flowing in the circuit.	It is used for finding the potential difference in the circuit.
Circuit	Circuit must be disconnected .	Circuit does not need to be disconnected.
Accuracy	Considered as less accurate.	Considered as more accurate.

Problem : A galvanometer has a resistance of 30 ohm and a current of 2mA is needed to give a full-scale deflection. What is the resistance needed and how is it to be connected to convert the galvanometer :

(a) into an ammeter with a range of 0.3 ampere.

(b) into a voltmeter with a range of 0.2 volt.

Solution : Here, galvanometer resistance G = 30Ω and full-scale deflection current Ig = 2 mA



(a) To convert the galvanometer into an ammeter of range 0.3 ampere, a resistance of value ' S ' is connected in parallel with it such that the current through G should not be more than I_g= 0.3A and $(I - I_g)$ should pass through S.

$(I - I_g) S = I_g G$

$S = I_g G/(I - I_g)$

$= 2 \times 10^{-3} \times 30/(0.3 - 2 \times 10^{-3}) = 0.2\ \Omega$

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(b) To convert the galvanometer into a voltmeter of range 0.2 volt, a resistance R is connected in series with it such that

$V = I_g (R + G)$

i.e. $0.2 = 2 \times 10^{-3} (30 + R)$

$R = 100 - 30 = 70\ \Omega$

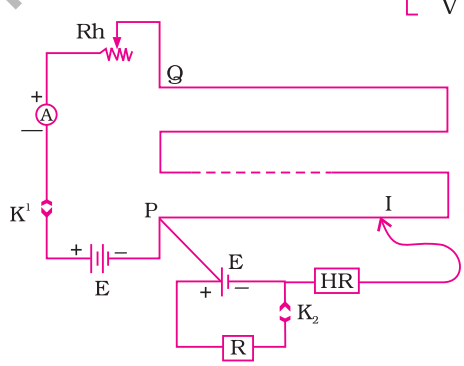
- **Potentiometer :** It is a device used to measure the internal resistance of a cell, to compare the e.m.f. of two cells and potential difference across a resistor. It consists of a long wire of uniform cross sectional area and of 10 m in length. The material of wire should have a high resistivity and low temperature coefficient. The wires are stretched parallel to each other on a wooden board. The wires are joined in series by using thick copper strips. A metre scale is also attached on the wooden board.
- **Principle :** It works on the principle that when a constant current flows through a wire of uniform cross sectional area, potential difference between its two points is directly proportional to the length of the wire between the two points.
- **Relation between e.m.f, potential difference and internal resistance of a cell**
- If a cell of emf E and internal resistance *r* is connected to an external resistance R, then the circuit has the total resistance (R + *r*). The current I in the circuit is given by,

$I = \frac{E}{R + r}$ or $E = I(R + r)$

Hence, $V = IR = E - Ir$

- It means that V is less than E by an amount equal to the fall of potential inside the cell due to its internal resistance.
- From the above equation, $\frac{r}{R} = \frac{E - V}{V}$

Or, the internal resistance of the cell, $r = R\left[\frac{E - V}{V}\right]$



- Using a potentiometer, one can adjust the rheostat to obtain the balancing lengths l_1 and l_2 of the potentiometer for circuit when open and closed respectively.

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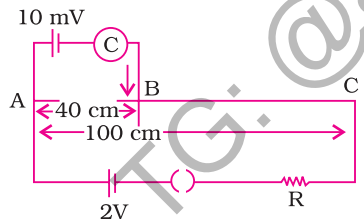
- Then, $E = k\, l_1$ and $V = k\, l_2$, where k is the potential gradient along the wire.
- Now, one can modify the equation for getting the internal resistance of the given cell, by using the above relations as:

$$r = R\frac{(l_1 - l_2)}{l_2}$$

- **Potentiometer v/s Voltmeter :** A voltmeter cannot be used for measuring the emf of a cell because a voltmeter draws some current from the cell. To measure a cell's emf, a potentiometer is used because in a potentiometer, there is no flow of electric current.

Problem : A potentiometer wire of length 100 cm has a total resistance of 10Ω. It is connected in series with a resistance R and a cell of emf 2 volts and of negligible internal resistance. A cell of emf 10 mV is balanced against a length of 40cm of potentiometer wire. What is the value of the external resistance R ?

Solution : As shown in the figure, if R is the unknown resistance, the current in the circuit I = V/(R + r) = 2/(10+R)



- Now as a 100-cm wire has a resistance of 10 Ω,the resistance of 40 cm of wire will be 40 × (10/100) = 4 Ω
- Potential drop across 40 cm wire will be V = I × 4 but here V = 10 mv (given) and I = 2/(10+R) = 1/400, *i.e.* R = 790 Ω.

Household circuits : All the household circuits are arranged in parallel. These circuits are connected with three different wires of different colour insulation, red/brown for live wire, black/blue for neutral wire and green/yellow for earth wire. In all these three wires, the earth wire is used as satety wire because it carries all the current if leaked to the body of electrical appliance that carried to the earth at zero potential and hence, protecting the uses of the appliance.

Any form of over withdrawal of current from the circuit or unfortunate connecting of live wire. With neutral wire or vice-versa causes the short circuit, the major cause of electrical fires in the domestic or industrial electric fires.

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Chapter 19

ELECTROMAGNETISM

Electromagnetism, electric current and magnetic field, Right-hand thumb rule, solenoid, S.I. units, properties of a bar magnet, characteristics of magnetic lines of force, magnetic permeability and types of substances, hard and soft magnetic materials, Gauss' law, Lenz's law, Ampere circuital law, Electric motor, Faraday's law of electromagnetic induction, electric generator and transformer.

- **Electromagnetism :** It has two meanings, depending on whether viewed at the subatomic level or on an everyday scale.
- At the subatomic level, electromagnetism is defined as the force between electrically charged particles. It is considered as one of the fundamental interactions of matter. Oscillating electrical charges result in electromagnetic waves such as light waves, radio waves, microwaves, etc. depending on the frequency of oscillation.
- On a larger scale, electromagnetism is the creation of a magnetic field from the movement of electrical charges. It usually concerns the use of electric current to make electromagnets, which is called electrodynamics.
- **Electric current and magnetic field :** When electric current is passed through a wire, a magnetic field is created around the wire. It was first observed and discovered by Hans Christian orested in 1820 when he made a surprising observation that a compass needle deflected away from magnetic north when the electric current from the battery he was using was switched on and off. This deflection convinced him that magnetic field is radiated from all sides of a wire carrying an electric current.
- Looping the wire in form of a solenoid greatly increases the magnetic field. Placing of an iron core in the centre of solenoid further increases the magnetic field producing an electromagnet.
- **Right-hand rule or Thumb rule :** When electric current is passed through a wire, a magnetic field rotates around the wire in a specific direction. It states that when the right hand is wrapped around a wire with the thumb pointing in the direction of the electric current, the fingers wrapped around it into point the direction of magnetic field, *i.e.* if the direction of current through a wire is from south to north, the direction of magnetic field is anticlockwise or vice versa as shown in the figure.

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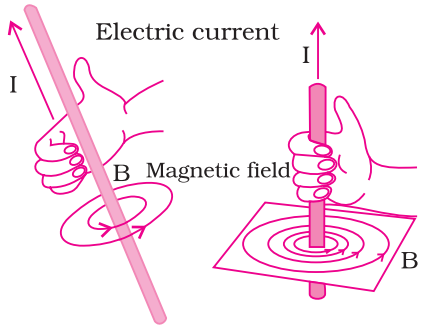
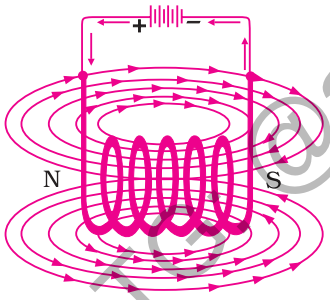


- **Solenoid :** A coil of wire with its length greater than its radius is called a solenoid as shown in the figure. When the current is passed through it, magnetic field develops around and inside it.



- The strength of the magnetic field developed depends on
  - the number of turns per unit length of solenoid.
  - the area of cross-section, a solenoid with a small area of cross-section produces a stronger magnetic field as compared to the one with a large area of cross-section.
  - the resistivity of the wire material.
- The end of the solenoid connected to the positive terminal of the battery acts as north pole and end connected to the negative terminal as south pole of a bar magnet.

SI electromagnetism units

Symbol	Name of Quantity	Derived Units	Unit	Base Units
G; Y; B	conductance; admittance; susceptance	siemens	S	$kg^{-1}.m^{-2}.s^{3}.A^{2}$ (= Ω^{-1})
B	magnetic flux density, magnetic induction, magnetic flux	tesla	T	$kg.s^{-2}.A^{-1}$ (=Wb/ M^2=$N.A^{-1}.m^{-1}$

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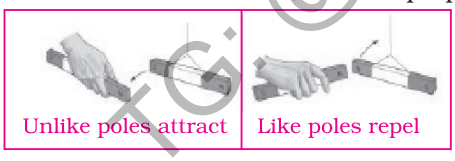
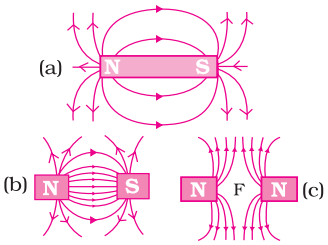
H	magnetic field strength	weber ampere per metre	Wb A.m	$kg.m^2.s^{-2}.A^{-1}$ (= V.s)
L,M	inductance	henry	H	$kg.m^2.s^{-2}\ A^{-2}$ (= Wb/A = V.s.A)
μ	permeability	henry per metre	H/m	$kg.m.s^{-2}.A^{-2}$.
χ	magnetic succeptibility	(dimensionless)	–	–

- **Magnetism :** It refers to the phenomenon of attracting magnetic substances like iron, nickel, cobalt, etc.
- A body possessing the property of magnetism is called a magnet. One of these properties is the that a magnet possesses poles at its ends where magnetism is the most concentrated in a magnet. The earth behaves as a natural magnet. A bar of iron when left buried in earth for some time, develops magnetic properties. The region around a magnet in which it exerts force on other magnets and on objects made of iron is called its magnetic field.
- **Properties of a bar magnet :** The properties of a bar magnet include :
  - A bar magnet when suspended freely aligns itself along geographical north-south direction. (Directive property)



  - The unlike poles of two magnets attract each other while the like poles repel (Attractive property). Repulsion is considered as the surest test of magnetism because its only two magnets that would undergo repulsion.
  - The magnetic poles always exist in pairs irrespective of the size of a magnet, they cannot be segregated from each other.
  - A magnet induces magnetism in other magnetic substances when brought close to it. Therefore, an iron bar placed close to a magnet, temporarily develops magnetic properties.
- **General Properties of Magnetic Lines of Force:** Magnetic lines of force have a number of important properties, which include :



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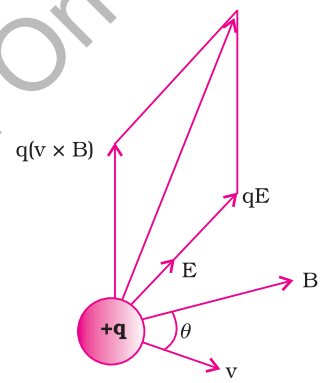
- They seek the path of the least resistance between opposite magnetic poles. In a single bar magnet as shown, they attempt to form closed loops from pole to pole.
- They never cross or interesect one another.
- They all have the same strength.
- Their density decreases (they spread out) when they move from an area of higher permeability to an area of lower permeability.
- Their density decreases with increasing distance from the poles.
- They are considered to have direction as if flowing, though no actual movement occurs.
- They flow from the south pole to the north pole within a material and from the north pole to the south pole in the air.

➢ **Magnetic force :** It is attractive or repulsive force that arises between electrically charged particles because of their motion. It is the basic force responsible for such effects as the action of electric motors and the attraction of magnets for iron. Electric forces exist among stationary electric charges, both electric and magnetic forces exist among moving electric charges. The magnetic force between two moving charges may be described as the effect exerted upon either charge by a magnetic field created by the other.

➢ The magnetic force F on the second particle is proportional to its charge q_2, the magnitude of its velocity v_2, the magnitude of the magnetic field B_1 produced by the first moving charge, and the sine of the angle θ, between the path of the second particle and the direction of the magnetic field :



i.e. $$F = q_2 B_1 v_2 \sin\theta$$

➢ Magnetic force is zero if the second charge is travelling in the direction of the magnetic field and is the greatest if it travels at right angles to the magnetic field. The magnetic force on a moving charge is exerted in a direction at a right angle to the plane formed by the direction of its velocity and the direction of the surrounding magnetic field.

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- **Magnetic permeability :** Magnetic permeability μ (Greek mu) is defined as, $\mu = B/H$
- **Magnetic flux density B** is a measure of the actual magnetic field within a material considered as a concentration of magnetic field lines or flux per unit cross-sectional area.
- Magnetic field strength H is a measure of the magnetizing field produced by electric current flowing in a coil of wire.
- In empty or free space, the magnetic flux density is the same as the magnetizing field because there is no matter to modify the field. In CGS units, the permeability B/H of space is dimensionless and has a value of 1. In SI units, B and H have different dimensions, and the permeability of free space (symbolized μ_0) is defined as equal to 4×10^{-7} weber per ampere-metre so that the SI unit of electric current may be the same as the practical unit, the ampere. In these systems the permeability, B/H, is called the absolute permeability μ of the medium. The relative permeability μ_r is then defined as the ratio μ/μ_0, which is dimensionless and has the same numerical value as the permeability in the CGS system. Thus, the relative permeability of free space or vacuum is 1.
- **Magnetic permeability and types of materials** : Materials may be classified magnetically on the basis of their permeabilities.
- **Diamagnetic materials** : These materials have a constant relative permeability slightly less than 1. When a diamagnetic material, such as silver, beryllium, bismuth, etc is placed in a magnetic field, the external field is partly repelled or expelled, and the magnetic flux density within it is slightly reduced, *i.e.* it acquires feeble magnetization but in the opposite direction.
- **Paramagnetic materials :** These materials have a constant relative permeability slightly more than 1. When a paramagnetic material, such as aluminium, platinum, manganese, chromium, etc. is placed in a magnetic field, it becomes slightly magnetized in the direction of the external field.
- **Ferromagnetic material :** These materials such as iron, cobalt and nickel do not have a constant relative permeability. As the magnetizing field increases, the relative permeability increases and reaches a maximum, and then decreases. Purified iron and many magnetic alloys have maximum relative permeabilities of value 100,000 or more.
- **Antiferromagnetism :** The only element exhibiting antiferromagnetism at room temperature is chromium. It is similar to ferromagnetic materials but the exchange interaction between neighbouring atoms leads to the anti-parallel alignment of atomic magnetic moments. Hence, the magnetic field cancels out and the material appears to behave in the same way as a paramagnetic material.

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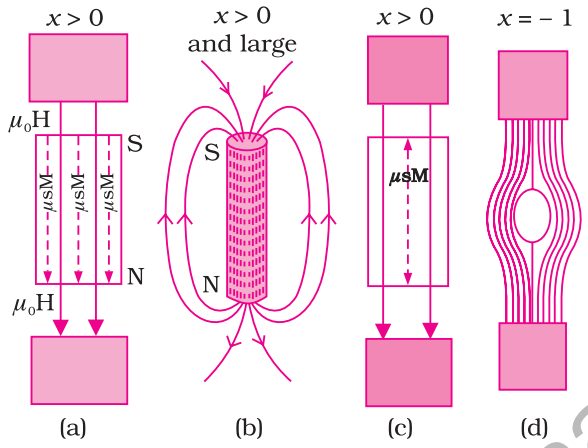

Ferromagnetic materials become paramagnetic above a transition temperature, known as the Neel's temperature, T_N. (Cr: T_N =37°C).

- **Ferrimagnetism :** It is only observed in compounds, which have more complex crystal structures than pure elements. Within these materials the exchange interactions lead to the parallel alignment of atoms in some of the crystal sites and anti-parallel alignment of others. The material breaks down into magnetic domains, just like a ferromagnetic material and the magnetic behaviour is also very similar, although ferrimagnetic materials usually have lower saturation magnetisations. For example in barium ferrite ($BaO.6Fe_2O_3$) the unit cell contains 64 ions of which the barium and oxygen ions have no magnetic moment, 16 Fe^{3+} ions have moments aligned parallel and 8 Fe^{3+} aligned anti-parallel giving a net magnetization parallel to the applied field but with a relatively low magnitude as only '+ve' of the ions contribute to the magnetisation of the material.

Hard magnetic materials v/s soft magnetic materials:

Hard Magnetic Materials	Soft Magnetic Materials
The materials which retain their magnetism and are difficult to be demagnetized.	Soft magnetic materials are easy to be magnetized and demagnetized.
These materials retain their magnetism even after the removal of the applied magnetic field.	They lose magnetism with time.
They have large hysteresis loss due to large hysteresis loop area.	They have low hysteresis loss due to small hysteresis area.
Susceptibility and permeability are low.	Susceptibility and permeability are high.
Coercivity and retentivity values are large.	Coercivity and retentivity values are small.

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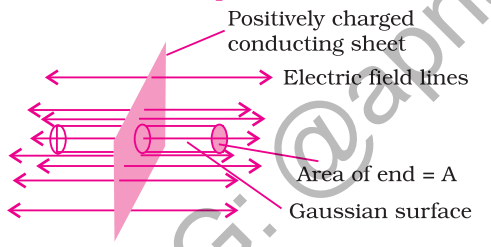
Magnetic energy stored is high.	Since they have low retentivity and coercivity, they are not used for making permanent magnets.
They possess high value of BH product.	Magnetic energy stored is less.
The eddy current loss is high.	The eddy current loss is less because of high resistivity.

Electric flux v/s magnetic flux :

- **Electric flux** is defined as the number of field lines or the concentration of field lines of an electric field perpendicular to a surface. From Gauss' Law, the value of electric flux through a closed surface is given by $\phi = q_{enclosed}/\in$
- From Ampere-Faraday's laws, a rate of change in electric flux has the ability to induce an emf (potential difference).



- **Magnetic Flux :** It is quite similar to electric flux with the number of magnetic field lines or the concentration of magnetic field lines perpendicular to a given surface. It's because monopoles, *i.e.* only North or only South poles are not known to exist. The magnetic flux through any closed surface is always zero as the number of field lines going into the surface equals to the number of (imaginary) field lines coming out.
- A changing magnetic field with respect to time also has the ability to induce an emf. A property is explained by Lenz's law.
- **Magnetic properties and hysteresis loop :** A number of primary magnetic properties of a material can be determined using hysteresis loop. These include:
- **Retentivity :** A measure of the residual flux density corresponds to the saturation induction of a magnetic material. In other words, it is the ability of a material to retain a certain amount of residual magnetic field when the magnetizing force is removed after achieving saturation. (The value of B at point b on the hysteresis curve.)
- **Residual Magnetism** or **Residual Flux :** It's the magnetic flux density that remains in a material when the magnetizing force is zero. The residual magnetism and retentivity are the same when the material has been magnetized to the saturation point. However, the level of residual magnetism may be lower than the retentivity value when the magnetizing force does not reach the saturation level.

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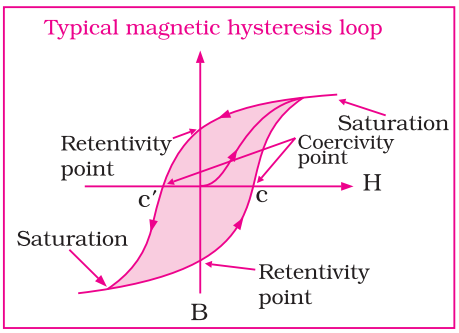

- **Coercive Force :** The amount of reverse magnetic field that must be applied to a magnetic material to make the magnetic flux return to zero. (The value of H at point C on the hysteresis curve.)
- **Permeability :** A property of a material that describes the ease with which a magnetic flux is established in the component.
- **Reluctance :** It refers the opposition that a ferromagnetic material shows to the establishment of a magnetic field. Reluctance is analogous to the resistance in an electrical circuit.
- **Hall effect:** It is the mobile charges, *i.e.* electrons in conventional conducting materials that are negatively charged. *Hall effect is meant* to determine whether the mobile charges in a given conductor are positively or negatively charged.
- Consider a thin, flat, uniform, ribbon of some conducting material which is orientated so that its flat side may be perpendicular to a uniform magnetic field B. Suppose we pass current *I* along the length of the ribbon. There are two alternatives. Either the current is carried by positive charges moving from left to right or it is carried by negative charges moving in the opposite direction. If the current is carried by positive charges moving from left to right, these charges should get deflected *upward* by the magnetic field. Thus, the upper edge of the ribbon becomes positively charged, while the lower edge becomes negatively charged. Consequently, there is a *positive* potential difference V_H between the upper and lower edges of the ribbon. This potential difference is called the Hall voltage.
- Hall voltage is proportional to the current flowing through the ribbon, and the magnetic field-strength, and is inversely proportional to the number density of mobile charges in the ribbon, and the thickness of the ribbon.

$$V_H \propto \frac{IB}{qnd}$$

- **Gauss' law :** According to the law, the electric flux through any closed surface is directly proportional to the net electric charge enclosed by that surface. The electric flux through a closed surface S

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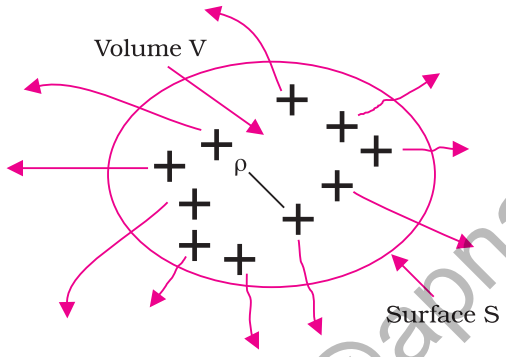
is written $\Phi_E = \int_S E.\, dS$. Similarly, the magnetic flux through a closed surface can be written as $\Phi_B = \int_S B.\, dS$. An immediate corollary of the above law is that the number of magnetic field-lines which enter a closed surface is always equal to the number of field-lines which leave the surface. In other words, *Magnetic field-lines form closed loops which never begin or end.*



Electric field v/s Magnetic field:

- An **electric field** occurs wherever a voltage is present. Electric fields are created around appliances and wires wherever a voltage exists. The strength of the electric field produced is proportional to the voltage. It is measured in volts per metre (V/m). The strength of an electric field decreases rapidly as one moves away from the source. Electric fields can also be shielded by many objects, such as trees or the walls of a building.
- **Magnetic fields** are created whenever there is a flow of electric current. With increase in the amount of current flowing, the level of magnetic field increases too. Magnetic fields are measured in milliGauss (mG).

Electric lines of force v/s Magnetic lines of force

	Electric field	**Magnetic field**
Nature	Created around electric charge	Created around moving electric charge and magnets
Units	Newton per coulomb, volts per metre	Gauss or Tesla
Force	Proportional to the electric charge	Proportional to charge and speed of electric charge
Movement in Electromagnetic field	Perpendicular to the magnetic field	Perpendicular to the electric field
Pole	Monopole or dipole	Dipole only

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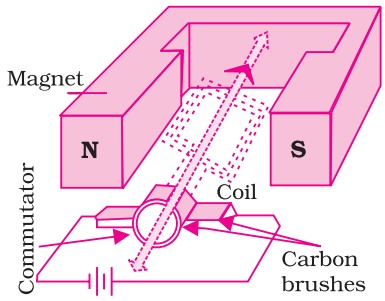
	Electrostatics	Magnetism
Dipole moment	p	m
Equatorial Field for a short dipole	$\frac{-p}{4\pi Eor^3}$	$\frac{\mu_0 m}{4\pi r^3}$
Axial Field for a short dipole	$\frac{2p}{4\pi \in or^3}$	$\frac{\mu_0 2m}{4\pi r^3}$
External field -Torque	P × E	m × B
Energy	–P.E	–m.B

- **Fleming left-and right-hand rule :** In the late 19th century, John Ambrose Fleming introduced both these rules to describe the relation between magnetic field, current and force. This relation is directionally determined by Fleming Left-Hand rule and Fleming Right-Hand rule respectively. 'Directionally' means these rules do not show the magnitude but show the direction of any of the three parameters (magnetic field, current or force) if the direction of the other two is known.
- **Fleming Left-Hand rule :** It is mainly applicable for an electric motor. According to the rule, if the left hand is stretched out with the forefinger, second finger and the thumb at right angle to one another. If the fore finger represents the direction of the field and the second finger that of the current, then thumb gives the direction of the force.
- **Fleming Right-Hand rule :** It is mainly applicable for an electric generator. If the right hand is stretched out with the first finger, second finger and the thumb at right angle to one another and if the forefinger represents the direction of the line of force and the thumb points in the direction of motion or applied force, then second finger will point in the direction of the induced current.
- **Electric motor**; It is an electrical machine that converts electrical energy into mechanical energy. It consists of two essential components :
  - There's a permanent magnet (or magnets) around the edge of the motor case that remains static, so it's called the stator of a motor.
  - Inside the stator, there's the coil, mounted on an axle that spins around at high speed and this is called the rotor. The rotor also includes the commutator.



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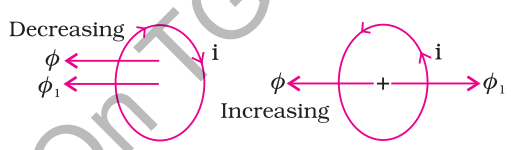
- When the current is passed, the rotator rotates to convert electrical energy into mechanical energy such as grinders, ceiling fans , etc.
- **Lenz's law :** The law considered analogous to Newton's third law in classic mechanics is the third law of electromagnetic induction. It is named after Russian physicist Heinrich Lenz who formulated it in 1834. The law states that :
- The direction of current induced in a conductor by a changing magnetic field due to Faraday's law of induction will be such that it creates a field that opposes the change that produced it.
- Lenz's law is shown by the negative sign in Faraday's law of induction : $\varepsilon = \frac{-d\phi}{dt}$

  which indicates that the induced voltage ε and the change in magnetic flux ($d\phi$) have opposite signs. It is a qualitative law that specifies the direction of induced current but says nothing about its magnitude.
- If the magnetic flux Φ linking a coil increases, the direction of current in the coil will be such that it will oppose the increase in flux and, hence, the induced current will produce its flux in a direction as shown below (using right-hand thumb rule).
- If magnetic flux Φ linking a coil is decreasing, the flux produced by the current in the coil is such that it will aid the main flux and, hence, the direction of current is as shown below :



Application of Lenz's Law :

- Lenz's law is used for understanding the concept of stored magnetic energy in an inductor.
- This law indicates that the induced emf and the change in flux have opposite signs which provides a physical interpretation of the choice of sign in Faraday's law of induction.
- Lenz's law is also applied to electric generators. When current is induced in a generator, the direction of this induced current is such that it opposes and causes rotation of generator and hence the generator requires more mechanical energy. It also provides back emf in case of electric motors.
- Lenz's law is also used in electromagnetic braking and induction cook tops.
- **Ampere's Circuital law:** This law is a useful relation that is analogous to Gauss' law. It merely explains a relationship between the tangential component of a magnetic field at points on a closed curve and the net current through the area bounded by the curve.

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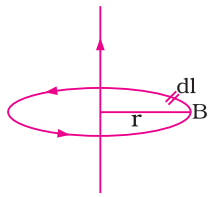
- The law is formulated in terms of the line integral of B around a closed path denoted by $\oint \vec{B}.\ \vec{dl}$
- We divide the path into infinitesimal segments dl and for each one calculate the scalar product of B and dl. In general, B varies from point to point and the B at the location of each dl must be used.
- Consider a long straight conductor carrying a current passing through the centre of a circle of radius r in a plane perpendicular to the conductor.



Using Biot Savart's law, the field at a distance r is

$$dB = \frac{\mu 0}{4\pi} \frac{I\ dl\ \sin\theta}{r^2}$$

the field at all points on the circle and the direction is given by the tangent drawn to the circle at that point

$$\oint B.dl = \oint \frac{\mu_0 I}{2\pi r}\ dl = \frac{\mu_0 I}{2\pi r} \oint dl$$

$\oint dl$ = circumference of the circle = $2\pi\rho$

$$\therefore\ B.\ dl = \mu_0 I$$

i.e. the flux is equal to the times the current threading through the area bounded by the circle. Hence, Ampere circuital law can be stated as follows :

- "The line integral of the magnetic field B around any closed path is equal to m_0 times the net current across the area bounded by the path."
- It does not necessarily mean that B = 0 everywhere along the path, but only that no current is linked to the path.
- **Faraday's Experiment :** Faraday performed an experiment with a magnet and coil. During this experiment, he found how emf is induced in the coil particularly when flux linked with it changes.
- **Relationship between induced emf and flux** when a bar magnet is held stationary or moved close or away from coil.

Position of magnet	Deflection in galvanometer
Magnet at rest	No deflection
Magnet moves towards coil	Deflection on one side
Magnet held stationary in or out of coil	No deflection
Magent is moved away the coil	Deflection in the opposite direction from when moved in

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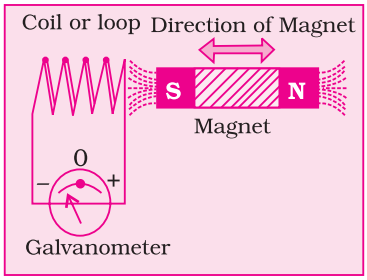

- From this experiment, Faraday concluded that whenever there is a relative motion between conductor and a magnetic field , the flux linkage with a coil changes and this change in flux induces a voltage across a coil. Based on his observations, he proposed two laws:
- **First Law :** It states that whenever the magnetic flux linked with a circuit changes, an e.m.f. is always induced in it or whenever a conductor cuts magnetic flux, an e.m.f. is induced in that conductor.
- **Second Law :** The magnitude of the induced e.m.f. is equal to the rate of change of flux linkages.
- Suppose a coil has N turns and flux through it changes from an initial value of $Ø_1$ webers to the final value of $Ø_2$ webers in time *t* seconds. But as flux linkages equals to the product of number of turns by the flux linked with the coil,

  Initial flux linkages = $NØ_1$

  Final flux linkages = $NØ_2$

  Induced emf is $e = \frac{N\phi_2 - N\phi_1}{t} \frac{wb}{s}$ or volt.

  $$c = \frac{N - \Delta\phi}{t}$$
- Putting the above equation in differential form, we get

  $$e = \frac{\theta}{dt}(N\phi) \text{ Volt}$$

  $$e = -N\frac{\theta}{dt} \text{ volt}$$
- Usually a minus sign is given to the right-hand side expression to signify the fact that the induced e.m.f. sets up current in such a direction that magnetic effect produced by it opposes the very cause producing it.
- **Electric generator:** It is a device that converts mechanical energy obtained from an external source into electrical energy as the output. It does not actually create electrical energy, it simply uses the mechanical energy supplied to it in forcing the movement of electrical charges present in the wire of its windings through an external circuit based on Fleming's left-hand rule and as described

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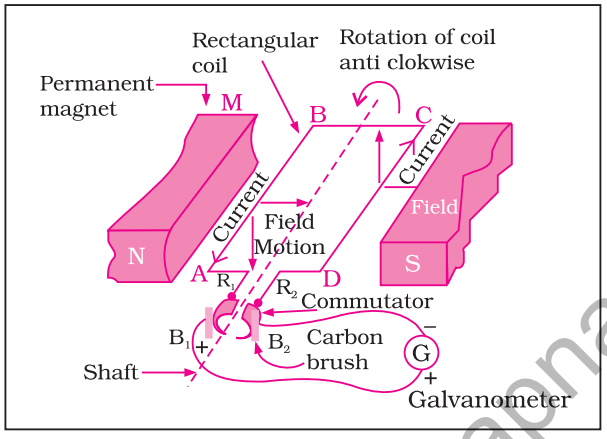
by Faraday's laws of electromagnetic induction. The flow of electrical charges constitutes the output electric current supplied by the generator.



- **Mutual induction :** When a current I flowing in the primary coil produces magnetic flux ϕ in hte secondary coil, then $\phi \alpha$ I or ϕ = MI where M is called the co-efficient of mutual induction. The unit for M in MKS system is hery but in CGS, it is ab-henry. (One henry = 10^9ab-henry)

$$e = \frac{-d\phi}{dt} = \frac{d}{dt}(MI) = -M\left(\frac{dI}{dt}\right)$$

For two coaxial solenoids, its is

$$M = \mu r\left(\frac{\mu_o}{4\pi}\right)\frac{4\pi n_1 n_2 A}{l}$$

where n_1 and n_2 are number of turns in primary and secondary coil.

- **Transformer :** In the simplest form, a transformer is simply a pair of coils wound on the same core. The core is often shaped as a square loop with *primary* and *secondary* coils wound on opposite sides. The construction of a transformer allows the magnetic flux generated by a current changing in one coil to induce a current in the neighbouring coil.
- Large transformers are a key component of the electrical distribution system. They are especially useful because the number of turns on each coil does not need to be the same. Because the EMF induced depends on the number of turns, transformers allow the voltage of an alternating current to be drastically stepped up or down. This is crucial as it allows high voltages to be used for efficiently distributing power over long distance with much safer lower voltages made available to consumers.

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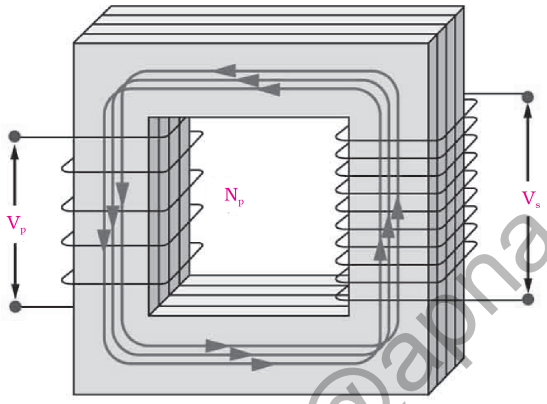
- For a transformer with no losses, the alternating voltage generated across a secondary coil V_s start subscript, s, end subscript depends on the alternating voltage across the primary coil *Vp* and the ratio of the turns in the primary and secondary coils $[N_s/N_p]$. Because energy is conserved, the maximum current available increases when the voltage is stepped down.



$$Vs = Vp\ (N_s\ /\ N_p)$$

- The relationship between the voltage and the number of turns in each coil is given by:

$$\frac{\text{Voltage in secondary coil}}{\text{Voltage in primary coil}} = \frac{\text{Turn on secondary coil}}{\text{Turn on primary coil}}$$

Or

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

- **Step up v/s step down transformer:** Transformers can be of two types :

1. **Step-up transformer :** This type of transformer has more turns on the secondary coil than primary coil. The induced voltage across the secondary coil is greater than applied voltage across the primary coil.
2. **Step-down transformer:** This type of transformer has less turns on the secondary coil than the primary coil. The induced voltage across the secondary coil is less than the primary applied voltage.

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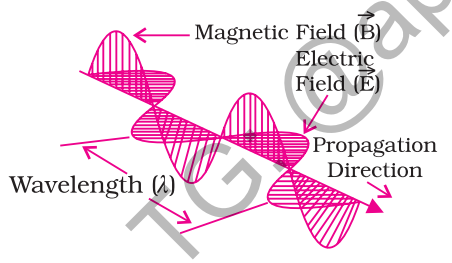
Chapter 20

ELECTROMAGNETIC WAVES

Electromagnetic spectrum, pros and cons of different forms of electromagnetic radiation, visible spectrum of light, its wavelength and frequency, photons, photoelectric effect, relation between threshold frequency and threshold wavelength with photoelectric effect respectively.

- **Electromagnetic spectrum :** It describes a wide range of different electromagnetic waves, also called EM waves. These are a special type of waves that can travel without a medium. Unlike sound waves and water waves, electromagnetic waves don't need any physical medium like fluid or a solid or air to propagate from one place to another. They can travel across the great vacuum of space with the speed of light, *i.e.* 3×10^8m/s.

Electromagnetic Wave



- Electromagnetic waves have both an electric and a magnetic component. They begin when charged particles, like electrons, vibrate due to the various forces acting on them. The vibration of charged particles results in an emission of energy known as electromagnetic radiation.
- EM waves propagate outward from the source. Just like regular transverse waves, the oscillations of EM waves are perpendicular to the direction of the wave propagation.
- EM waves are complicated waves. In these waves the electric component oscillates in one plane, while magnetic component oscillates in a different plane as shown above in the figure.
- **Range of electromagnetic spectrum:** The EM spectrum includes the range of all possible frequencies of electromagnetic waves. At one end of the spectrum are the waves with the lowest frequencies *i.e.*, radio waves, and at the other end are the highest frequency waves., the gamma rays. EM waves can also be distinguished by their wavelength and frequency being inversely proportional to each other. One can view electromagnetic spectrum not only in terms of increasing frequencies but also in terms of decreasing wavelengths. As frequencies increase in the EM spectrum, wavelengths decrease i.e. if the radio waves have the largest wavelengths and lowest

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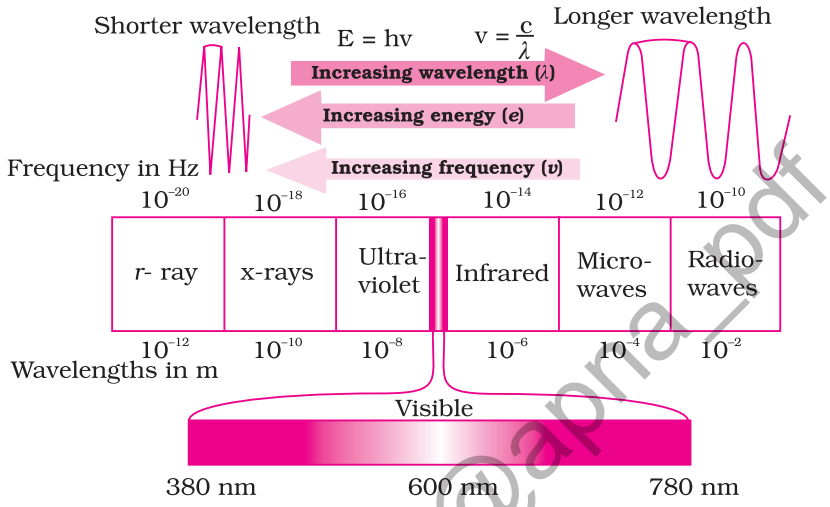
frequencies are present at one end while gamma rays with the smallest wave length and the largest frequencies are present at the other end.



- **Properties of electromagnetic waves :** E.M. waves are composed of oscillating electric and magnetic fields at right angles to each other and both are perpendicular to the direction of propagation of the wave. E.M. waves differ both in wavelength and frequency.
- The source that produces them and methods of their detection are different, but they have the following common properties :
  - They are propagated by oscillating electric and magnetic fields oscillating at right angles to each other even in vacuum.
  - They travel with a constant velocity of 3×10^8 ms^{-1} in vacuum.
  - They are not deflected by an electric or a magnetic field.
  - They are transverse waves which can show interference or diffraction and may be polarized.
  - Their wavelength (λ) and the frequency (ν) of electromagnetic wave is related as $c = v\lambda = \omega/k$
- The S.I. unit of frequency is Hertz (1 Hertz = cycle/s) and of wavelength is metre. However, wavelength is expressed in Angstrom unit (1 Å = 10^{-10} m) or nanometre(1 nm = 10^{-9} m).
- **Different EM waves, their pros and cons :** Different type of E.M. ways are advantageous along with some dangers associated with them as listed below;

Radio Waves (communications):

- TV and FM radio (short wavelength)
- Direct line of sight with transmitter (do not under go diffraction)

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- Medium wavelength fail to travel farther because they are reflected by layers in the atmosphere

(Microwaves) Satellite signals :

- Frequency of microwaves pass easily through atmosphere and clouds.
- While cooking food in a microwave oven as these waves pass through from the inside of food.
- Microwaves are absorbed by water molecules.These water molecules become heated to heat food.
- However, microwaves are absorbed by living tissus. This internal heating damages or kill cells.
- **Infra-red Radiation (remote controls, toasters) :** Any object that radiates heat radiates infra-red radiation. This is absorbed by all materials and causes heating
- It is used for night vision and security cameras as Infrared radiation is visible both in daytime or night time.
- Police use it to catch criminals, the army use it to detect enemy However, prolonged exposure to it damages (burns) to cells.

Ultraviolet rays :

- Their sanitary and therapeutic properties have a marked effect on architecture, engineering and public health.
- UV rays are germicidal therefore used in destroying bacteria, viruses and moulds in the air, in water and on surfaces.
- UV synthesises vitamin D in the skin, controls the endocrine system and is a painkiller.
- Used in state of the art air handling units, personal air purifiers and swimming pool technology.
- Used for detecting forged bank notes: they fluoresce in UV light; real bank notes don't. Used for identifying items outside visible spectrum areas, known as 'black lighting'.
- However, exposure to them is dangerous because
  - over exposure to UVA and UVB damages surface cells and eyes and can cause cancer.
  - skin burning is caused by high UVB which also give inadequate protection against free radical damage caused by UVA.

X-rays :

- X-rays detect bone breaks or fine fractures. as they pass through flesh but not dense material like bones.

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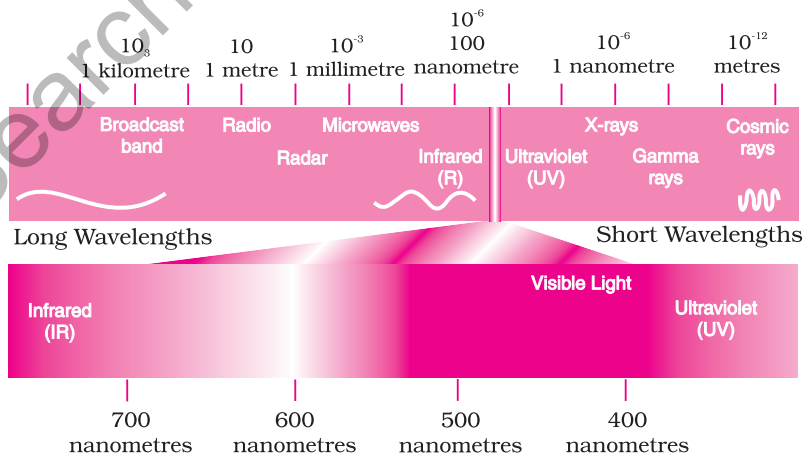
- X-rays damage cells and cause cancers. Radiographer precautions include wearing lead aprons and standing behind a lead screen to minimise exposure. Similarly, pregnant mothers are always advised to avoid exposure to X-rays.

Gamma Rays :

- Gamma rays can both cause and treat cancers.
- In high doses, gamma rays can kill normal cells and cause cancers.

- **Visible spectrum of light :** Light is a form of electromagnetic radiation. The human eye has the capability to detect or sense some part of the complete electromagnetic spectrum.
- The portion of the electromagnetic spectrum which is sensed by our human eye has wavelength in the range between 380nm and 750nm is called visible light. Visible light travels in a straight line and the speed of light in vacuum is equal to $c = 2.99792458 \times 10^8$ m s^{-1}. This is approximately taken as 3×10^8 ms^{-1}.
- **Wavelength of Visible Light :** Wavelength of the visible light ranges from 380 nm to 750 nm. In the electromagnetic spectrum, infrared rays have higher wavelength than the visible rays and the ultraviolet rays has smaller wavelength as compared to the visible light. Long wavelength visible light is the red visible light with wavelength that ranges from the 625 nm to the 750 nm. The smallest wavelength visible light is the violet visible light with wavelength that ranges from 380 nm to 435 nm.
- **Frequency of Visible Light :** It is defined as the number of crests which passes through a particular point in a second. It is represented in hertz. Frequency of waves is inversely proportional to their wavelength, which means the higher the wavelength, the lower is the frequency and vice versa. The frequency range of the visible light is between 400 to 790 THz.



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- **Visible Light Spectrum Chart :** Visible light consists of different types of colours. These colours are differentiated on the basis of their wavelengths in the visible spectrum. Visible Light Spectrum Chart is the breakdown of the colors present in the white light with respect to their wavelengths or frequencies. The Colours of Visible Light are Red, orange, yellow, green, and cyan, blue, violet.

Colour of light	Wavelength	Frequency
Violet	425 - 400 nm	700 - 790 THz
Indigo	450 - 425 nm	670 – 700 Thz
Blue	599 – 459 nm	670 – 700 THz
Green	579 – 500 nm	580 – 530 Thz
Yellow	590 – 570 nm	530 – 510 Thz
Orange	610 – 590 nm	510 – 480 Thz
Red	750 – 610 nm	480 – 405 Thz

(THz = 1000 Hz)

- Visible Light Energy: According to the particle theory of light, light consists of particles called as photons.
- Energy of the visible light is given by the formula : $E = hf$
  Where, E = Energy of the light wave, h = Planck's constant and f = frequency of the wave.

SI photometry quantities

Quantity		Unit		
Name	**Symbol**	**Name**	**Symbol**	**Notes**
Luminous energy	Q_v	lumen second	lm·s	Units are sometimes called talbots.
Luminous flux/ luminous power	Φ_v	lumen (= cd·sr)	lm	Luminous energy per unit time.
Luminous	I_v	candela (= cd.sr)	cd	Luminous power per unit solid angle.
Luminance intensity Luminance	L_v	candela per sq. metre	cd/m^2	unit projected source area. Units area. Units are sometimes called nits.
Luminous exitance/ luminous emittance	M_v	lux	lx	Luminous power emitted from a surface.
Luminous efficacy	η	lumen per watt	lm/W	Ratio of luminous flux to radiant flux or power consumption, depending on context.

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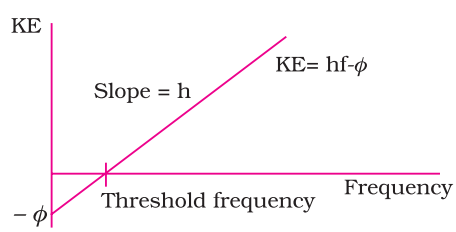
- **Photon:** It is a bundle of electromagnetic energy, the basic unit that makes up all light. It is sometimes referred to as a "quantum" of electromagnetic energy. It is a basic unit of nature called an elementary particle.
- **Properties of a Photon :** The properties include:
  - They have zero mass.
  - They have no electric charge and are stable.
  - They carry energy and momentum which are dependent on the frequency.
  - They can have interactions with other particles such as electrons. They can be destroyed or created by many natural processes. When in empty space, they travel at the speed of light.
  - Photons interact with matter, therefore, behave like particles.
- **Planck's Constant :** The relationship between the energy of a photon and its frequency is described by the equation: $E = hv$

  where, E is energy, v is frequency, and h is Planck's constant. Planck's constant is always the same (*i.e.* the "constant") and equals $6.62606957 \times 10^{-34}$ m^2 kg / s. (Js^{-1})
- The original concept of the photon was developed by Albert Einstein. However, it was scientist Gilbert N. Lewis who first used the word "photon" to describe it. The theory which states that light behaves both like a wave and a particle is called the wave-particle duality theory.
- **Photoelectric effect :** When a photon strikes the eye, it is turned into electrical energy, that is, it is then transmitted to the brain to form as an image. When the energy from photons is absorbed by matter, the matter can emit electrons. This process is called the photoelectric effect. The photoelectric effect is a property of light that is not explained by the theory that light is a wave. This is one of the main reasons that scientists chose to treat light as both a wave and a stream of particles.



- A material that can exhibit the photoelectric effect is said to be photoemissive. Electrons ejected by the photoelectric effect are called photoelectrons.

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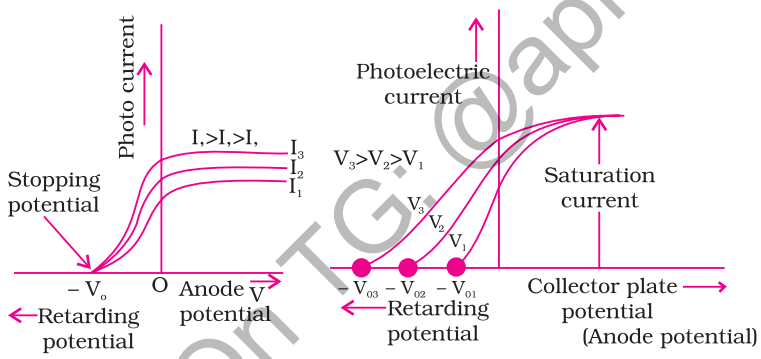
- The photoelectric effect will not occur when the frequency of the incident light is less than the threshold frequency with different materials having different threshold frequencies.
- For photoelectron emission to take place, $\lambda < \lambda_0$ and $\phi > \phi_o$
- The maximum kinetic energy of a stream of photo electrons is determined by measuring the stopping potential (the applied voltage needed keeps the photoelectrons trapped in the photoemissive surface). The maximum K.E. increases linearly with the frequency of the incident light above the threshold frequency but is independent of the intensity of the incident light.
- The rate at which photoelectrons are emitted from a photoemissive surface is determined by measuring the electric current.
- On a graph of maximum kinetic energy vs frequency, all curves are linear with slope equal to Planck's Constant. The intercept on the energy-axis is the threshold frequency of the material.



- **Challenges to classical physics :** Classical physics cannot explain why:
  - no photoelectrons are emitted when the incident light has a frequency below the threshold,
  - the maximum kinetic energy of the photoelectrons increases with the frequency of the incident light,
  - the maximum kinetic energy of the photoelectrons is independent of the intensity of the incident light, and
  - there is essentially no delay between the bsorption of the radiant energy and the emission of photoelectrons.
- **Modern physics and electromagnetic radiation**: It states that
  - electromagnetic radiation is composed of discrete entities called photons
  - the energy of a photon is proportional to its frequency
  - the work function of a material is the energy needed per photon to extract an electron from its surface.

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Equations :

Photoelectric effect : $K_{max} = E - Q = h(F - F_0)$

Photon energy:

$$E = hf = \frac{hc}{\lambda}$$

- **Work function :** It refers to the minimum amount of energy required to eject an electron from the outermost surface of a metal.

  $\phi = hf_o = hc/\lambda_o$

  where f_o *and* λ_o are threshold frequency and threshold wavelength respectively.

- **Stopping potential:** It is also called cut off potential for a particular frequency of incident radiation, the maximum –ve potential V_o given to plate for which the emission of photoelectrons becomes zero, *i.e.* $K_{max} = eV_0$

Problem : The work function of potassium is 2.8 eV. Calculate the maximum kinetic energy of an electron emitted when potassium is illuminated with the ultraviolet radiation of wavelength 100 nm.

Solution : The energy E of a 100nm photon is given by

$E = h\,c\,/\,\lambda$

$E = 6.6 \times 10^{-34} \times 3 \times 10^{8}\ /\ 100 \times 10^{-9}$

$E = 2 \times 10^{-18}$ J = 12.5 eV

Maximum kinetic energy E_{max} of an emitted photon is given by

$E_{max} = E - \phi$

$E_{max} = 12.5 - 2.8 = 9.7\ eV$

Problem : A certain metal surface, when illuminated by the light of frequency 6 × 1014 Hz, emits photoelectrons with a maximum kinetic energy of 1.1 eV. Calculate the work function of the metal.

Solution : The energy E of each photon is given by

$E = hf$

$E = 6.6 \times 10^{-34} \times 6 \times 10^{14}$

$E = 4 \times 10^{-19}$ J = 2.5 eV

The work function of the metal is related to the maximum kinetic energy E_{max} of photoelectrons by Einstein's photoelectric equation

$E_{max} = hf - \phi$

$\phi = hf - E_{max}$

$\phi = 2.5 - 1.1 = 1.4\ eV$

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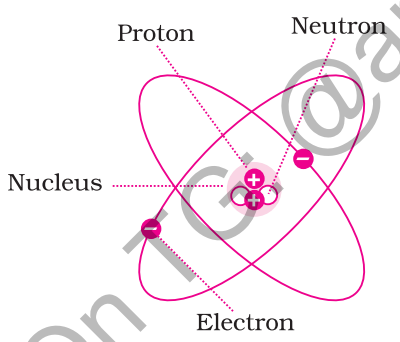
Chapter 21

NUCLEAR PHYSICS

Structure of atom, nucleus and nucleons, binding energy, alpha decay, beta decay, electron capture, spontaneous decay,, radioactive decay, half life of radioactive elements, nuclear fission, fissile materials v/s fissionable materials, nuclear fusion , applications of radioactivity and radioactive elements, types of nuclear power plants, power producing nuclear power plants.

- **Structure of the Atom :** The atoms of every element is composed of the nucleus at the centre and electrons revolving around it about just as planets circling around the sun. The nuclei of atoms are composed of protons, that have a positive electrical charge, and neutrons, which are electrically neutral. Electrons are electrically negative and have a charge equal in magnitude to that of a proton.



- The number of electrons in an atom is normally equal to the number of protons in the nucleus. As a result, atoms of elements are normally electrically neutral. The mass of an atom lies almost entirely in its nucleus since protons and neutrons are far more heavier than electrons. (Mass of an electron is 1/1837 times of mass of a proton)
- Free neutrons are unstable particles which decay naturally into a proton and an electron, with a half-life of about 12 minutes.

  Neutron → Proton + Electron + a neutrino
- However, neutrons when exist together with protons in the nucleus of atoms, are stable. The energy balance in the decay of a neutron is achieved by the anti-neutrino, a neutral particle that carries off surplus energy as the neutron decays.
- **Mass number :** The nominal mass of an atom of an element is measured by the sum of the protons and the neutrons in it. This nominal mass of an atom is not affected by the number of electrons, which are very light. Hence, the nominal mass based on the mass number, *approximates* the actual atomic mass.

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- **Atomic number :** It refers to the number of protons in the nucleus, which determines the chemical properties of an element. Elements are arranged in ascending order of atomic number in an arrangement called the periodic table.
- **Radioactive Decay :** The nuclei of some elements are not stable. These nuclei are radioactive. They emit energy and particles, collectively called "radiation". All elements have one or more isotopes that are radioactive.
- All isotopes of heavy elements with mass numbers greater than 206 and atomic numbers greater than 83 are naturally radioactive.
- There are several ways in which unstable nuclei undergo radioactive decay :
- **Alpha decay :** It involves the emission of a helium-4 nucleus containing two protons and two neutrons. This is the least penetrating form of radiation. It is stopped by the dead layer of skin and so does no harm when outside the body. But it is the most damaging form of radiation when deposited inside the body.
- Many heavy nuclei emit an energetic alpha particle when they decay. For instance, uranium-238 decays into thorium-234 with a half-life of almost 4.5 billion years by emitting an alpha particle:

$$_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4}$$

- The mass number of uranium-238 (radioactive element) declines by four and its atomic number by two when it emits an alpha particle.
- **Beta decay :** It involves the emission of an electron or a positron (a particle identical to an electron except that it has a positive electrical charge).
- In beta decay, the atomic number increases by one if an electron is emitted or decreases by one if a positron is emitted. For instance, thorium-234, which is the decay product of uranium-238, in turn undergoes beta-decay into protactinium-234 by emitting an electron:

$$_{90}Th^{234} \Rightarrow {}_{91}Pa^{234} + {}_{-1}e^{0}$$

- **Electron capture :** It involves the capture of an electron by the nucleus from among the ones whirling around it. In effect, the electron combines with a proton to yield a neutron.
- **Spontaneous fission :** It involves the fission of a heavy element without input of any external particle or energy.
- Often, there is still excess residual energy in the nucleus after the emission of a particle or after the capture of the electron. Some of this residual energy after radioactive decay can be emitted in the form of high-frequency electromagnetic radiation, called gamma rays.
- **Gamma rays :** These are essentially like X-rays and are the most penetrating form of radiation. However, the emission of gamma rays does not change the mass number or atomic number of the nucleus that is, unlike radioactive decay by the emission of particles, spontaneous fission or electron capture. Hence, it does not cause the transmutation of the nucleus into another element.

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- Each quantum or unit of a gamma ray (or other electromagnetic energy) is called a photon. These gamma rays can damage living cells by splitting molecules apart or ionizing elements present in them.
- **Balancing of a nuclear reaction :** The number before the element name is the atomic number and that after the element name is the mass number. The totals of the atomic numbers and the mass numbers, respectively, on both sides of the nuclear reaction must be the same. (This is like balancing a chemical equation, in which the number of atoms of each element on both sides of the reaction must be equal)
- **Half-life :** It is the time taken for half the initial atoms to decay (or transmute into another element or nuclear state). At the end of one half-life, half the original element is left, while the other half is transformed into another element. After two half-lives, one-fourth of the original element is left after three half-lives one-eighth is left, and so on. This results in the build-up of decay products. If the decay products themselves decay into other elements, a whole host of radioactive materials come into being. The decay products of radioactive elements are also called daughter products or progeny.

  It N is the number of atoms left undecayed after *n*–half-lives then $\frac{N}{N_o} = \left(\frac{1}{2}\right)^n$, where *No* is the initial number of atoms.

  Similary if M_o be the initial mass and M left undecayed after *n*-half lives then $\frac{M}{M_o} = \left(\frac{1}{2}\right)^n$

  It A_o be the initial activity and *A* be the activity after *n*–half-lives, then $\frac{A}{A_o} = \left(\frac{1}{2}\right)^n$
- **Binding Energy :** Nuclei are tightly bound together by the strong nuclear force and each nucleus has a characteristic binding energy. This is the amount of energy it would take to completely break up a nucleus and separate all the neutrons and the protons in it. Typically, binding energy increases by several mega electron-volts (MeV) for every proton or neutron added to a nucleus. (Since protons and neutrons are constituent particles of nuclei, they are known collectively as nucleons.) The release of nuclear energy derives from the differences in binding energy between the initial nucleus (or nuclei) and relative to the end-products of the nuclear reaction, such as fission or fusion.
- The binding energy is the amount of *energy that would have to be added to the nucleus to break it up.* It can be thought of (approximately) as the amount of energy liberated when a nucleon is drawn into the nucleus due to the short range nuclear attractive force. Since energy and mass are equivalent, *nuclei with higher binding energy per nucleon have a lower atomic weight per nucleon.*

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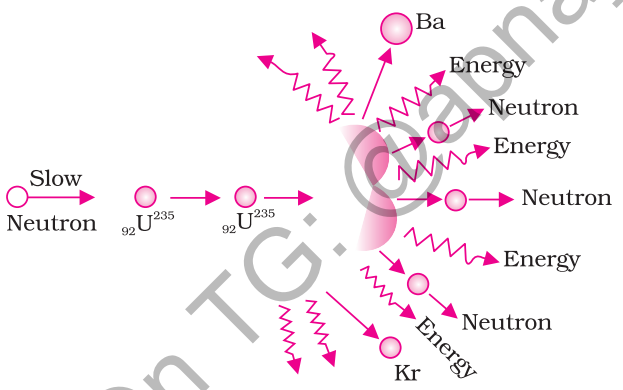
- **Key for release of nuclear energy :** The key to the release of nuclear energy from the fission of heavy elements and fusion of light elements is that elements in the middle of the periodic table of elements, with intermediate mass numbers have a higher binding energy per nucleon (that is a lower atomic weight per nucleon). Therefore, when a heavy nucleus undergoes fission, the resultant products of the nuclear reaction have a slightly smaller combined nuclear mass. This mass difference is converted to energy during nuclear fission following Einstein's relation $E = mc^2$
- Where m is the mass defect and c is the velocity of light.
- **Nuclear Fission:** Nuclear energy is produced by the conversion of a small amount of the mass of the nucleus of an atom into energy. The amount of energy released in nuclear fission is equivalent to the energy content of over three million metric tons of coal.



- Heavy atoms such as uranium or plutonium can be split by bombarding them with neutrons. The resultant fragments, called fission products, are of intermediate atomic weight, and have a combined mass that is slightly smaller than the original nucleus. The difference appears as energy.
- **Aspect of energy and mass in nuclear fission :** The energy and mass aspects of the fission process can be explained mathematically as follows:
- Let the total binding energy of the heavy nucleus and the two fission products be B_h, B_{f1} and B_{f2} respectively. Then:
- Amount of energy released per fission $E_r = (B_{f1} + B_{f2}) - B_h$
- Amount of mass converted to energy = $Er/c^2 = \{(B_{f1} + B_{f2}) - B_h\}/ c^2$
- This energy appears in various forms: the kinetic energy of the neutrons, the vibrational energy of the fission fragments and gamma radiation. All of these forms of energy are converted to heat by absorption with the surrounding media in the reactor, mainly the coolant and the moderator (for thermal reactors).

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- **Nuclear reactor and nuclear fission :** The most basic fission reaction in nuclear reactors involves the splitting of the nucleus of uranium-235 when it is struck by a neutron. The uranium-235 first absorbs the neutron to yield uranium-236, and most of these U-236 nuclei split into two fission fragments. Fission reaction typically also releases two to four neutrons (depending on the speed of the neutrons inducing the fission and probabilistic factors). One of these neutrons triggers another fission for a sustained chain reaction. The fission reactions in a nuclear reactor can be written generically as follows:

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{92}U^{236} \rightarrow x + y + \text{neutrons}$$

U-236 ⇒ fission fragments + 2 to 4 neutrons + 200 MeV energy (approx.)

- The uranium-236 nucleus does not split evenly into equal fission fragments. Rather, the tendency, especially with fission induced by thermal neutrons, is for one fragment to be considerably lighter than the other. An example of a fission reaction is:

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{92}U^{236}$$

$$_{92}U^{236} \rightarrow {}_{38}St^{90} + {}_{54}x^{144} + 2\,{}_{0}n^{1} + \text{energy}$$

- While many heavy nuclei can be fissioned with fast neutrons, only a few can be fissioned with "slow" neutrons. It turns out that, with some exceptions, like plutonium-240, only nuclei that can be fissioned with slow neutrons can be used for sustaining chain reactions.
- **Fissile materials v/s Fissionable materials :** Isotopes with nuclei that can be fissioned with zero energy neutrons (in practice neutrons with low energy, or "slow neutrons") are called *fissile* materials. Generally, these are the odd-numbered isotopes, such as uranium-233, uranium-235 plutonium-239, and plutonium-241. Other heavy nuclei, like uranium-238, can be fissioned with fast neutrons, and so are *fissionable*, but not fissile.
- There are only three fissile isotopes of practical importance: uranium-233, uranium-235, and plutonium-239. Of these, only uranium-235 occurs naturally in significant quantities. The other two occur in trace quantities only.
- **Fertile Materials :** To obtain plutonium-239 and uranium-233 in amounts useful for nuclear energy production, they must be manufactured from materials that occur in relative abundance. Plutonium-239 is produced from reactions following the absorption of a neutron by uranium-238. Uranium-233 is produced by neutron absorption in thorium-232.
- Therefore, uranium-238 and thorium-232 are called fertile materials. The production of fissile materials from them is called breeding or enrichment of material.

Reactions for plutonium-239 are

$$_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{92}U^{239}$$

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$_{92}U^{239} \rightarrow {}_{93}Np^{239} + {}_{0}e^{-1}$

$_{93}Np^{239} \rightarrow {}_{94}Pu^{239} + {}_{0}e^{-1}$

Reactions for uranium-233 are:

$_{90}Th^{232} + {}_{0}n^{1} \rightarrow {}_{90}Th^{233}$

$_{90}Th^{233} \rightarrow {}_{91}Pa^{233} + {}_{0}e^{-1}$

$_{91}Pa^{233} \rightarrow {}_{92}U^{233} + {}_{0}e^{-1}$

- **Nuclear fusion :** Nuclear energy can also be released by the fusion of two light elements (elements with low atomic numbers). The power that fuels the sun and the stars is nuclear fusion. In a hydrogen bomb, two isotopes of hydrogen, deuterium and tritium, are fused to form a nucleus of helium and a neutron. This fusion releases 17.6 MeV of energy. Unlike nuclear fission, there is no limit on the amount of the fusion that can occur.
- A fission bomb, called the primary, produces a flood of radiation including a large number of neutrons. This radiation impinges on the thermonuclear portion of the bomb, known as the secondary. The secondary consists largely of lithium deuteride. The neutrons react with the lithium in this chemical compound, producing tritium and helium, *i.e.* $_{3}Li^{6} + {}_{0}n^{1} \rightarrow {}_{2}He^{4} + {}_{1}H^{3}$
- This reaction produces the tritium on the spot, so there is no need to include tritium in the bomb itself. In the extreme heat which exists in the bomb, the tritium fuses with the deuterium in the lithium deuteride.

Examples of artificial radioactivity :

- $_{7}N^{14} + {}_{o}n^{1} \rightarrow {}_{6}C^{14} + {}_{1}H^{1}$
  $_{6}N^{14} \rightarrow {}_{7}N^{14} + {}_{1}e^{o}$
- $_{5}B^{10} + {}_{2}He^{4} \rightarrow {}_{7}N^{13} + {}_{o}n^{1}$
  $_{7}N^{13} \rightarrow {}_{4}C^{13} \rightarrow {}_{-1}e^{o}$
- $_{13}A^{127} + {}_{2}He^{4} \rightarrow {}_{15}p^{30} + {}_{o}n^{1}$
  $_{15}P^{30} \rightarrow {}_{14}Si^{30} \rightarrow {}_{1}e^{o}$

Units used for measuring ionizing radiation and radiation dose

Unit	Description	Equivalent
Rem (roentgen equivalent man)	The dose in rem equals the dose in rad multiplied by the quality factor (Q). For beta and gamma radiation, the quality factor is taken as one, that is, rem equals rad. For alpha radiation, the quality factor is taken as 20, that is, rems equal 20 times rads. Rem is essentially a measure of biological damage. For neutrons, Q is typically taken as 10.	rem = rad x Q

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Sievert (Sv)	A unit of equivalent absorbed dose equals 1 to 100 rem.	Sv = 100 rem Sv = Gy x Q
Rad (radiation absorbed dose)	A unit of absorbed dose of radiation. Rad is a measure of the amount of energy deposited in tissue. (erg/gram)	1 rad = 100
Grey (Gy)	A unit of absorbed radiation dose equal to 100 rad. Grey is a measure of deposition of energy in tissue.	1 Gy = 100 rad
Curie (Ci)	The traditional unit of radioactivity, equal to the radioactivity of one gram of pure radium-226.	billion dps = 1 Ci = 37 = 37 billion
Becquerels (Bq)	The standard international unit of radioactivity equals one disintegration per second.	1 Bq = 27 pCi
Disintegrations per second (dps)	The number of subatomic particles (e.g. alpha particles) or photons (gamma rays) released from the nucleus of a given atom over one second. One dps = 60 dpm (disintegrations per minute).	1 dps = 1 Bq

Problem : The half-life period of yttrium is 20 minutes. If there is a 1000 grams of yttrium present, how much will be left after 30 minutes?

Solution : Given: initial no of radioactive elements N_o = 1000g.

Half-life $t_{1/2}$ = 20 min,

Time taken t = 30 min,

Decay Constant is given by

$\lambda = 0.693/t_{1/2}$

= 0.693/20min

= 0.03465

The Decay rate is given by

$N_t = No\ e^{-\lambda t} = 1000\ e^{-0.03465(30)}$

= 1000 ×× 0.3536 = 353.63 g.

353.63 g of atoms will be present after 30 min.

Problem : If you are given with 500 grams of radioactive carbon. Calculate the decay rate after 60 minutes if the half-life period is about 30 minutes.

Solution : Initial no. of atoms N_0 = 500g.

Half-life period $t_{1/2}$ = 30 min

Time taken t = 60 min

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The decay constant is $\lambda = 0.693/t_{1/2}$
= 0.693/30 minutes
= 0.0231
The decay rate is given by
$N_t = N_o e^{-\lambda t} = 500 e^{-(0.0231)60}$
= 500 ×× 0.25 = 125.04 g.

Problem : A radioactive isotope has a radioactivity measured on a Geiger-Muller tube at 10,000 Becquerel's or 10,000 counts per second. What is the activity of the radioisotope after 3 half lives?

Solution : The amount remaining = $1/2^n$ x original amount
The amount remaining = $1/2^3$ x 10,000
The amount remaining = 1/8 x 10,000
The amount remaining = 1250 Bq

Applications of radiations :

- **Radiation in treatment of cancer :** The three types of radiation are highly energetic particles. Each type has its own distinct ionising and penetrating property. Alpha radiation can ionise the molecules in living cells, in particular the DNA molecule. This can affect the ability of the cell to grow and divide. This affect of radiation on living cells is made use of in the treatment of cancer.
- The process of using radiation in the treatment of cancer is called radiation therapy or radiotherapy. During radiotherapy both cancer cells and normal cells are damaged, however, normal cells can recover from the effects of radiation.

There are three types of radiation therapies:

- **External radiation therapy** used for treat types of cancers, e.g., cancer of the breasts, brain, bladder, lungs, etc. It is also used in certain cases when cancer is malignant, *i.e.* spreads to the other parts of the body from the primary site.
- **Internal radiation therapy :** The radioactive isotopes used in internal radiation therapy are Iodine 125 or Iodine 131, Strontium 89, Phosphorous, Palladium, Cesium, Iridium or Cobalt. As the isotopes decay naturally, they emit radiation which target the nearby concerous cells.
- **Systemic radiation therapy** employed in the treatment of some types of thyroid cancer using iodine 134.

  Radio sodium-24 is used for removing defects in blood circulation.

  Radio phosphorus-32 is used in treatments of skin diseases, blood cancer and leukemia.
- **Radiocarbon or Carbon-14 dating :** It is a technique used by scientists for dating bones, wood, paper and cloth. Carbon-14 is a radioisotope of carbon. It is produced in the earth's upper atmosphere when Nitrogen-14 is broken down to form the unstable Carbon-14 by the action of cosmic rays. The unstable Carbon-14 is transported down to the lower atmosphere by atmospheric activities such as storms.

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- The ratio of Carbon-14 with half-life of 5730 years to Carbon-12 atoms in the organism is the same as the ratio in the atmosphere. Once an organism dies, it stops taking in carbon in any form. The unstable Carbon-14 within the organism begins to decay to form Nitrogen-14 by emitting a beta particle. Overthe time, there is a gradual decrease in the amount of Carbon-14 and the ratio of Carbon-14 atoms to other Carbon atoms declines. By measuring the ratio of Carbon-14 in a sample and comparing it to the amount in a recently deceased sample, its date can be determined
- **Gamma rays in sterilization :** The process by which an object is exposed to radiation is called irradiation. Gamma irradiation can be used for preserving foods. The radioisotope Cobalt-60 is used as the source for gamma rays. The gamma rays formed from this source kill bacteria, moulds, parasites and insects. They also inhibit germination and premature ripening in fruits and vegetables. This helps to prolong the shelf life of the food. The food itself does not become radioactive.
- **Beta radiation in leak detection :** Leaks in underground pipelines can be detected by the injection of a radioactive isotope. This is achieved by adding a small amount of a radioisotope which is a source of beta radiation to the fluid. The area above ground where a high intensity of beta radiation is detected will pin-point the leak source in the pipeline. This saves time as the correct area is dug up.
- **Alpha particles in smoke detection :** Radioactive isotopes which emit alpha particles can be used in smoke detectors. Smoke detectors make use of the ionising properties of alpha particles. Americium-241 with half-life of 432 years is a good source of alpha particles. The long half-life is useful as it ensures a continuous source of alpha particles which means that the detector is very reliable and will not stop functioning soon once installed.
- When smoke enters the ionisation chamber, the alpha particles collide with the smoke particles instead of the air particles. The collision with smoke particles does not result in ionisation, so the current drops. The electric circuit registers the drop in electric current and triggers the alarm to beep.
- **Nuclear reactor :** All nuclear reactors are devices designed to maintain a chain reaction producing a steady flow of neutrons generated by the fission of heavy nuclei. They are, however, differentiated either by their purpose or by their design features. In terms of purpose, they are either research reactors or power reactors.
- **Research reactors :** These reactors are operated at universities and research centres in many countries, These reactors generate neutrons for multiple purposes, including producing radio pharmaceuticals for medical diagnosis and therapy, testing materials and conducting basic research.
- **Power reactors :** These are found in nuclear power plants to generate heat, mainly for the production of electricity.

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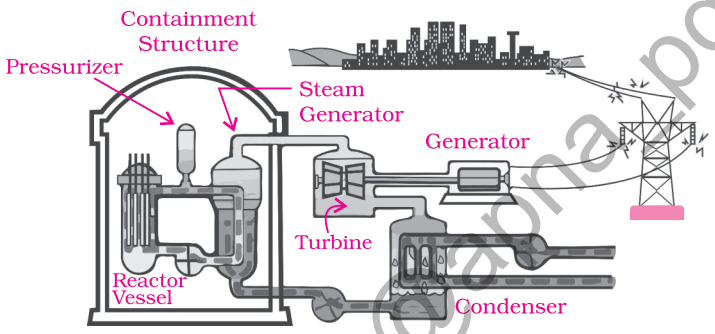
- **Nuclear Power Reactors :** These reactors involve the fission of heavy atomic nuclei, the most common of which is uranium-235, to produce heat that is transferred to a fluid which acts as a coolant. During the fission process, bond energy is released that first becomes noticeable as the kinetic energy of the fission products generated and also of the neutrons being released. Since these particles undergo intense deceleration in the solid nuclear fuel, the kinetic energy turns into heat energy.

The Pressurized-Water (PWR)



- In case of reactors designed to generate electricity, the heated fluid can be gas, water or a liquid metal. The heat stored by the fluid is then used either directly (in case of gas) or indirectly (in case of water and liquid metals like sodium) to generate steam which is then fed into a turbine driving an alternator.

  The use of nuclear power reactors shows the use of nuclear radioactive materials for the peacefull purpose.
- **Types of Nuclear Power Reactors :** It is common practice to classify power reactors according to the nature of the coolant and the moderator plus, as the need may arise, other design characteristics.

Reactor Type	Coolant	Moderator	Fuel
Pressurised water reactor (PWR, VVER)	Light water	Light water	Enriched uranium
Boiling water reactor (BWR)	Light water	Light water	Enriched
Pressurised heavy water reactor (PHWR)	Heavy water	Heavy water	Natural uranium
Gas-cooled reactors (Magnox, AGR, UNGG)	CO_2	Graphite	Natural or enriched uranium
Light water graphite reactor (RBMK)	Pressurized boiling water	Graphite	Enriched uranium

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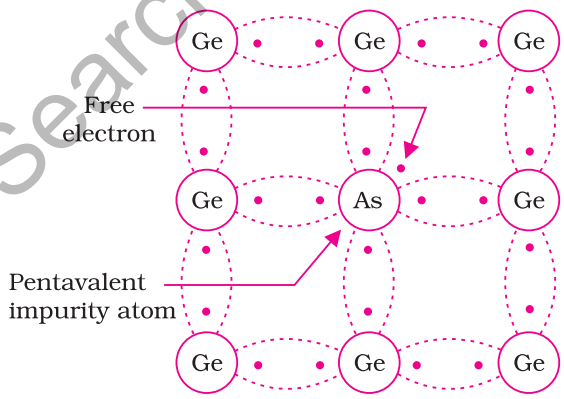
Chapter 22

SEMICONDUCTORS AND DEVICES

Semiconductors and their types– Types of semiconductors, diodes, triodes, inverter v/s converter, transistors, transistor as a switch, transistor as an amplifier.

- Classification of semiconductors: There are two basic groups or classifications that can be used to define the different types of semiconductors:
- **Intrinsic material :** An intrinsic type of semiconductors material is made to be very pure chemically. As a result, intrinsic material possesses a very low conductivity level having a very few number of charge carriers, namely holes and electrons, which it possesses in equal quantities.
- **Extrinsic material :** Extrinsic types of semiconductors materals are those where a small amount of impurity is added to the basic intrinsic material. This 'doping' uses an element from a different periodic table group hence, it will either have more or less electrons in the valence band than the semiconductors itself. This creates either an excess or shortage of electrons. In this way two types of semiconductors are produced.
- **N-type :** An N-type semiconductor material has an excess of electrons. In this way free electrons are available within the lattices and their overall movement in one direction under the influence of a potential difference results in an electric current flow. Therefore, in an N-type semiconductor the charge carriers are electrons.



(a) N-type semiconductor

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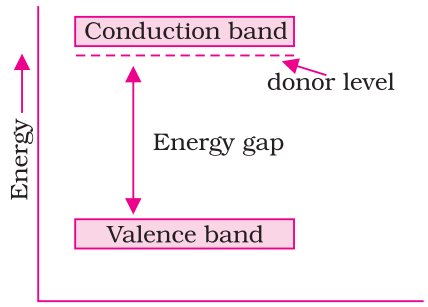
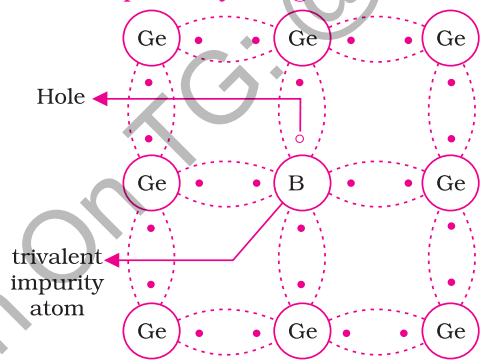
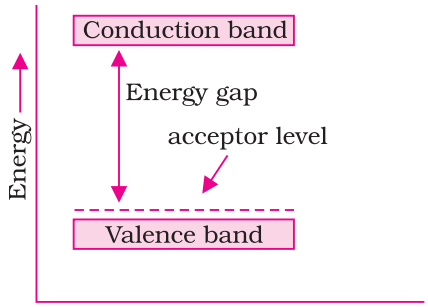


(b) Energy band diagram of N-type semiconductor

➢ **P-type :** In a P-type semiconductor material, there is a shortage of electrons, *i.e.* there are 'holes' in the crystal lattice. Electrons may move from one empty position to another and in this case, it can be considered that the holes are moving. This can happen under the influence of a potential difference and the holes can be seen to flow in one direction resulting in an electric current flow. It is actually harder for holes to move than for free electrons to move and, therefore, the mobility of holes is less than that of free electrons. Holes are positively charged carriers.



(a) P-type semoconductor



(b) Energy band diagram of a P-type semiconductor

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➢ **List of semiconductor materials :** There are many different types of semiconductor materials that can be used within electronic devices. Each has its own advantages, disadvantages and areas where it can be used to offer the optimum performance.

MATERIAL	CHEMICAL SYMBOL/ FORMULA	DETAILS
Germanium	Ge	It was used in many early devices from radar detection diodes to the first transistors.
Silicon	S	It is the most widely used type of semiconductor material. Its major advantage is that it is easy to fabricate and provides good general electrical and mechanical properties. Another advantage is that when it is used for integrated circuits, it forms high-quality silicon oxide that is used for insulation layers between different active elements of the IC.
Gallium arsenide	GaAs	It is the second most widely used type of a semiconductor. It is widely used in high performance RF devices where its high electron mobility is utilised. It is also used as substrate for other III-V semiconductors, e.g. InGaAs and GaIn As. However it is a brittle material and has a lower hole mobility than silicon.
Silicon carbide	SiC	It finds uses in power devices where its losses are quite low and operating temperatures are higher than those of silicon-based devices. Silicon carbide has a breakdown capability which is about ten times that of silicon itself.
Gallium nitride	GaN	It is starting to be more widely used in microwave transistors where high temperatures and powers are needed. It is also being used in some microwave ICs. It has been used in some blue LEDs.
Gallium phosphide	GaP	It has found many uses within LED technology from low to medium brightness LEDs producing a variety of colours depend on the addition of other dopants. Pure Gallium phosphide produces a green light, when nitrogen-doped, it emits yellow-green and when ZnO-doped, it emits red.
Cadmium sulphide	CdS	It is used in photoresistors and solar cells.

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Lead sulphide	PbS	It is used as the mineral galena in the very early radio detectors known as 'Cat's Whiskers' where a point contact was made with the tin wire onto the galena to provide the rectification of the signals.

- **Number of terminals and types of semiconductors:** Semiconductors are used in a number of applications, but can be divided into four categories, based on the number of terminals the semiconductor has: Two-terminal, three-terminal, four-terminal, and multi-terminal. The number of terminals on a device determines what it be used for.
- **Diode :** It is a two-terminal device whose state is dependent on the external power current to which it is connected. A diode has two active electrodes, between which a signal flows, following the direction of the current flow. The function of a diode, on a basic level, is to direct the flow of electrical current, allowing it to flow in one direction but not the other. LEDs are the famous example of a two-terminal device, and are used in a number of industries.

  An ideal diode when forward biased offers zero resistance and acts as a short circuit. When reverse biased offers infinite resistance and act as an open circuit.
- **Knee voltage :** It is defined as the forward voltage at which the current through the junction starts increasing rapidly.
- **Diode, forward or reverse biased :** In *p–n* Junction diode when p-side is connected to +ve terminal and n-side to –ve terminal of battery. The diode is called towards biased. When p-side is connected to –ve terminal and n-side to +ve terminal of the battery, the diode is said to be reverse biased. A battery acts as a reverse bias to majority charge carriers but fowards biased for minority carriers.
- **Triode :** It is a three terminal device whose state is dependent not only on its external power circuit, but also the signal on its driving terminal or gate. Triodes transfer the electrical resistance. These can be used as amplifiers, switches or in oscillators. They can be used individually in discrete components, or in large numbers as part of an integrated circuit (IC).
- **Four-terminal device :** It converts a signal from one form of energy to another form of energy. These devices have a source, gate, drain and body terminal, and are used for amplifying and switching electronics signals and power, much like three-terminal devices. For example, these four-terminal devices can be used in a light switch circuit, converting high power to low power for use in domestic lighting.
- **Multi-terminal devices**: These devices have a number of terminals that can perform a number of operations. The most common of these are integrated circuits, which are used in virtually all

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electronic equipments today. Because the terminals are printed on the semiconductor material, usually silicon, all at the same time, rather than connected one by one, these devices are affordable and relatively quick to produce. The construction of these devices also allows for quicker functions.

Inverter v/s Converter :

	Converter	Inverter
Meaning	Electrical devices used for converting the voltage from alternating current (AC) to direct current (DC).	Electrical devices used for converting the voltage from direct current (DC) to alternating current (AC).
Types	Analog-to-digital converter (ADC), Digital-to-analog converter (DAC), Digital-to-digital converter (DDC)	Square wave inverter Quasi wave or Modified square wave inverter True/Pure Sine wave inverters
Applicatons	Convert, AC to DC; detects signals; supplies polarized voltage for welding	Convert DC electricity from solar panels, batteries, fuel cells to AC for electric grids.
Disadvantages	Poor current overload capacity; better quality; automatic regulators are more expensive than mechanical regulators.	Not ideal for inductive AC and motor loads; sensitive electronic devices can be damaged by poor waveforms by low batteries

- **Transistor :** It is a semiconductor device used for amplifying or switching electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the terminals of the transistor which controls the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. These transistors are found embedded in integrated circuits.
- Their use has revolutionized the field of electronics, and paved the way for smaller and cheaper radios, calculators, and computers, among other things.
- **Types of transistors :** There are two types of transistors.
  1. *Bipolar transistor : It* has terminals labelled base, collector and emitter. A small current at the base terminal (that is, flowing between the base and the emitter) can control or switch a much larger current between the collector and emitter terminals.
  2. *Field-effect transistor* : It has the terminals labelled as gate, source and drain, and a voltage at the gate can control a current between source and drain.
- In transistors, the collector region is physically larger than emitter region. For its biasing, the emitter base junction is alwasy forward biased while the collecter based junction is always reverse biased.

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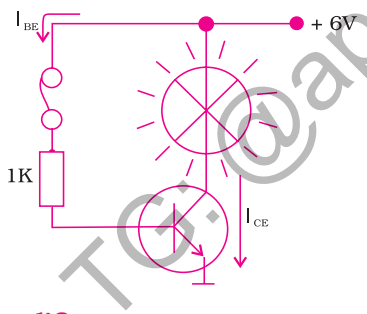
- **Transistor and circuit :** A transistor can be connected in a circut in the following three configurations; Common Base (CB), Common Emitter (CE) and Common Collector (CC).

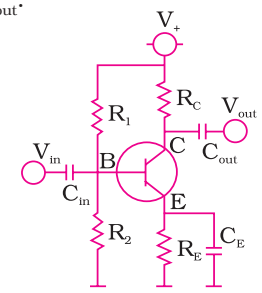
Transistor as a switch

- Transistors are commonly used in digital circuits as electronic switches which can be either in an "on" or "off" state In a grounded-emitter transistor circuit, such as the light-switch circuit shown, as the base voltage rises, the emitter and collector currents rise exponentially. The collector voltage drops because of reduced resistance from the collector to the emitter. If the voltage difference between the collector and emitter were zero (or near zero), the collector current would be limited only by the load resistance (light bulb) and the supply voltage. This is called *saturation* because current is flowing from the collector to the emitter freely. When tranistor is saturated, the switch is said to be *on* and when not , it is considered switched off.



Transistor as an amplifier

- The common-emitter amplifier is designed so that a small change in voltage (V_{in}) may change the small current through the base of the transistor; the current amplification of the transistor combined with the properties of the circuit means that small swings in V_{in} produce large changes in V_{out}.



- From mobile phones to televisions, vast numbers of products include amplifiers for sound reproduction, radio transmission and signal processing. Modern transistor audio amplifiers of up to a few hundred watts are common and relatively inexpensive.

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UNIT-II

CHEMISTRY

1. BASIC PRINCIPLES OF CHEMISTRY
2. STRUCTURE OF ATOM
3. PERIODIC CLASSIFICATION OF ELEMENTS
4. CHEMICAL BONDING AND MOLECULAR STRUCTURE
5. STATES OF MATTER : SOLIDS, LIQUIDS AND GASES
6. THERMODYNAMICS
7. EQUILIBRIUM
8. HYDROGEN AND ITS PROPERTIES
9. ALKALI METALS AND THEIR PROPERTIES
10. ALKALINE EARTH METALS AND THEIR PROPERTIES
11. CARBON FAMILY ELEMENTS AND THEIR PROPERTIES
12. CHALCOGENS, MEMBERS OF OXYGEN FAMILY
13. PNICTOGENS, MEMBERS OF NITROGEN FAMILY
14. HALOGENS
15. TRANSITION ELEMENTS
16. METALLURGY
17. SOLIDS
18. SOLUTIONS
19. ELECTROCHEMISTRY
20. CHEMICAL KINETICS
21. QUALITATIVE ANALYSIS
22. ORGANIC CHEMISTRY

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Chapter 1

Basic Principles of Chemistry

Chemistry, physical and chemical classification of states of matter, properties of solids, liquids and gases, properties of solutions, colloids and suspension, law of conservation of mass, law of constant composition, law of multiple proportions , law of reciprocal proportions, Gay Lussac's law, Dalton Atomic theory, Berzelius hypothesis, Avogadro's law, Concentration units, i.e. molarity, molality ,normality, mass per unit volume, parts per million and mole fraction.

- **Chemistry :** It is the branch of science that deals with the study of composition, properties, structure of matter and the changes which the matter undergoes in varying conditions and the laws which govern them.
- **Matter and its types :** Anything that occupies space and has its own mass and inertia is called matter.
- Matter can be classified both physically and chemically as listed in the flow-chart given below.

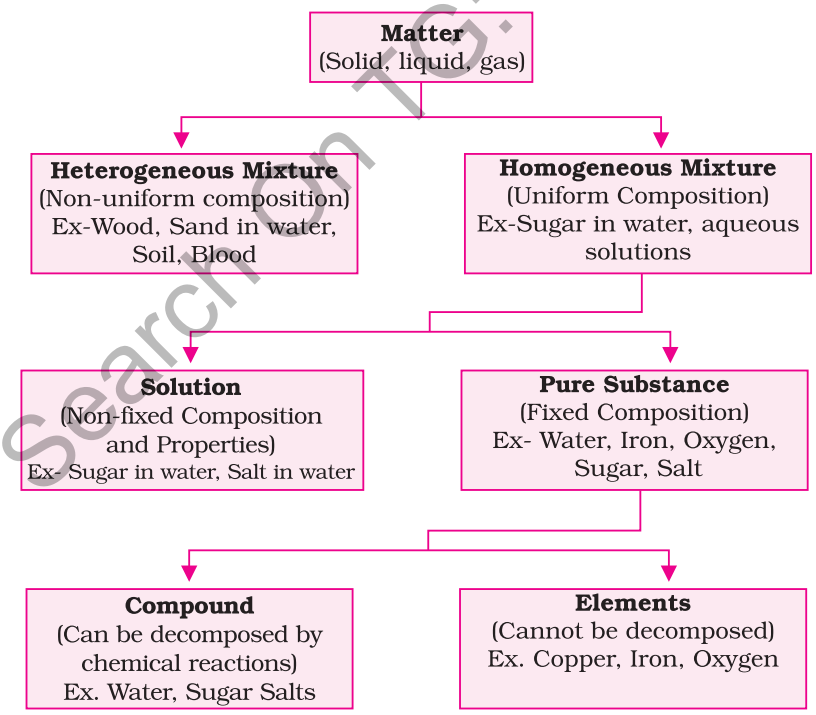

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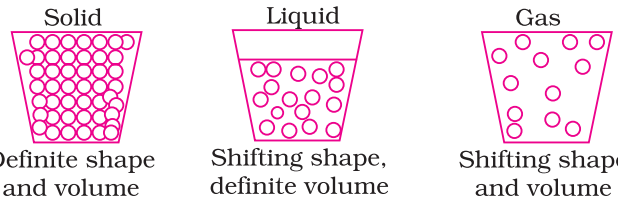
Table : Physical states of matter:

You have studied in earlier classes that matter exists in three physical states. These states differ from one another as listed below.



S No.	Solid	Liquid	Gas
1.	The molecules, atoms or ions are very closely packed that is why they are firm and tightly packed.	The particles are loosely packed than those in solid.	The particles are more loosely packed than those in solid and liquid.
2.	They are firmly held together by the force of cohesion. However, vibration and rotational motion about their fixed position is possible.	They are loosely held by the force of cohesion. Hence, they can vibrate, rotate, translate with minimum restriction and are no logner held in fixed position.	They are loosely held by the force of they can vibrate, they can vibrate, rotate, translate with no restriction.
3.	They have definite fixed mass.	They have definite fixed mass.	They have definite mass.
4.	They have definite shape.	They have indefinite shape.	They have indefinite shape.
5.	They have definite or fixed volume.	They have definite or fixed volume.	They have indefinite volume.

Concentration and units of related quantities	
Concentration unit	**S.I. unit**
Mass concentration	kg/m^3 (equal to g/L).
Molar concentration	mol/m^3. However, more commonly the unit mol/L (= mol/dm^3) is used.
Volume concentration	Dimensionless; it is expressed as a number, e.g., 0.18 or 18%; its unit is 1.
Normality	Mol m^{-3}
Molarity	Mol L^{-1}
Molality	Mol kg^{-1}
Mole fraction	Sum of all mole fractions is equal to unity.

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- **Mixture :** It refers to the physical combination of two or more substances on which the identities are retained and are mixed in the form of solutions, suspensions or colloids. A mixture can be homogeneous or heterogeneous.
- **Homogeneous and Heterogeneous mixture**
- A homogeneous mixture is defined as "the mixture, which has uniform composition throughout its mass", e.g. air, sugar solution, salt solution, alloys, soft drinks (Pepsi, CocaCola, etc.).
- A heterogeneous mixture is defined as a mixture that does not have uniform composition throughout its mass, e.g., soil, rocks, mixture of iron filings and sulphur, etc.
- **Solution, colloid and suspension** : These three too represent the different forms of mixtures with varying properties as listed in the table given below.

Characteristic	Solution	Colloid	Suspension
Nature	Homogeneous	Visually homogeneous	Heterogeneous
Particle size	< 1nm	1nm -1mm	> 1mm
Stability	Physically stable	Physically stable	Needs stabilizing agent
Tyndall effect	No	Yes	Yes
Separation by centrifugation	No	Yes	Yes

- **Pure substance :** A substance with both definite and constant composition and its distinct chemical properties is called a pure substance. It can be an element or a compound.
- **Methods of separation :** These methods are adopted to extract a pure substance is characterized by its specific melting point (m.p.), boiling point (b.p), density, etc. from a mixture, These methods depend either on property of substance or the impurity present such as filtration, sieving. etc.
- **Crystallisation :** It is a method of separation used to separate pure substances such as sugar or salt from its respective saturated or super-saturated solution using a seedling.
- **Distillation :** It is a method of the separation of two miscible or immiscible liquids provided the two have the difference of minimum of 25°C in their respective boiling points. When the mixture of two is heated, the one with lower boiling point evaporates first and it's vapour is collected separately and condensed such as alcohol from water, benzene from toluene etc.
- **Fractional distillation :** It is a method used when the mixture has three or more ingredients having different boiling points such as the extraction of different gases from air or different fractions from petroleum.
- **Steam distillation :** The method involves the usage of steam for distillation such as in case of the distillation of eucalyptus oil from the fragmented leaves of the plant's, coconut seeds for coconut oil.

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- **Chromatography :** It is the method used for the separation of pigments primarily from a mixture of dyes or pigments. The method uses a specific type of paper called chromatographic paper with special features to allow the loaded solvent to rise to specific height on the paper, such as used in the separation of photosynthetic pigments from the extract of green leaves.

Element v/s Compound

Both an element and a compound are pure substances but an element is a pure substance that can neither be decomposed into nor built from any simpler substance by any simple physical or ordinary chemical method. Ex: Oxygen, Hydrogen, Chlorine, Copper, etc.

A compound is a pure substance formed by the union of two or more than two elements in a definite proportion by weight. The constituent elements of a compound can be separated by known chemical means, such as in electrolytic dissociation. Ex : Water (H_2O), Ammonia (NH_3), Methane (CH_4) etc.

Types of elements

There are 118 known elements which have further been classified into three types based on their chemical and physical properties. These are :

Metals	Non-metals	Metalloids
These are about 80% of known elements characterized by their properties of own bright lustre, ductility, malle-ability, corrosibility, good heat and electrical conductivity, high melting and boiling points. Chemically, most of them react with oxygen to form basic oxides and react with dilute acids to form respective salts producing hydrogen gas. Bromine is the only liquid non-metal; iodine is solid with metallic lustre. Other solid non-metals include carbon, silicon, sul-phur, etc.	These elements mostly found in gaseous state are characterized by their properties of poor conductivity of heat and electricity, low melting and boiling points. Chemically most of them react with oxygen to form acidic oxides and do not normally react with acids.	These are eight elements which share the properties of both metals and non-metals. These are boron, silicon , germanium, polonium, arsenic, antimony , tellurium and astatine.

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- **Types of compounds :** Primarily, all the known chemical compounds are of two types, called inorganic and organic compounds.

Organic compounds v/s Inorganic compounds
The main difference is in the presence of a carbon atom, organic compounds contain a carbon atom (and often a hydrogen atom, to form hydrocarbons), while almost all inorganic compounds do not contain either of these two atoms together. An another important distinction between organic and inorganic compounds is the type of molecule and its association with living things. Organic compounds include the nucleic acids, lipids and fatty acids found in the cells of living organisms, proteins and enzymes that are necessary for cellular processes to take place, and inorganic compounds include the salts, metals, and other elemental compounds, we see in our surrounding.

- **Laws of chemical combination :** These are laws generalized from the quantitative studies of chemical changes. There is a total of five laws in which four deal with mass relationship while the fifth deals with the volume of reacting gases. These five laws are:
- **Law of conservation of mass :** Mikhail Lomonosov in 1756 discovered and proposed the law of mass conservation. According to the law, mass in an isolated system is neither created nor destroyed by chemical reactions or physical transformations. The mass of the products in a chemical reaction is always equal to the mass of the reactants.
- **Law of definite proportion :** This law also called as the law of constant composition or Proust's law was proposed by the French chemist Joseph Proust, based on several experiments conducted between 1798 and 1804. It states that all samples of a given chemical compound have the same elemental composition by mass. For example, oxygen makes up about 8/9 of the mass of any sample of pure water, while hydrogen makes up the remaining 1/9 of its mass.
- **Law of multiple proportions :** It is also called as "Dalton's Law" after being discovered by the British chemist John Dalton. It states that when two elements combine to form more than one compound then the mass of one element, which combines with a fixed mass of the other element, is always in the ratio of whole numbers. *For* **example :** if hydrogen and oxygen form two compounds with the hydrogen content of 42.9% and 27.3% respectively. Than
- In the first compound, the mass of hydrogen is 42.9 g. and the mass of oxygen will be 100 - 42.9 = 57.1g.
- Therefore, the mass of hydrogen that combines with 1 g of oxygen = 42.9 / 57.1 = 0.75g

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- In the second compound the mass of hydrogen is 27.3g then the mass of oxygen will be 100 - 27.3 = 72.7g
- Therefore, the mass of hydrogen that combines with 1 g of oxygen = 27.3 / 72.7 = 0.375g
- Hence, the ratio of hydrogen combining with a fixed mass of oxygen in simple ratio of 0.75 : 0.375, *i.e.* 2:1 as stated by the above law.
- The law can also be proved by taking examples of different oxides of nitrogen, copper or iron.
- **Law of reciprocal proportion :** The law proposed by Jeremias Ritcher in 1792 states that, "If two different elements combine separately with the same weight of a third element, the ratio of the masses in which they do so are either the same or a simple multiple of the mass ratio in which they combine". E.g. both oxygen and sulphur react with copper to give copper oxide and copper sulphide, respectively. Sulphur and oxygen also react with each other to form SO_2. Therefore,

  in CuS Cu:S = 63.5:32 and in CuO Cu:O = 63.5:16

  Therefore, S:O = 32:16 or S:O = 2:1

  In SO_2 S:O = 32:32 or S:O = 1:1

  Thus, the ratio between the two ratios is $\frac{2}{1}\times\frac{1}{1}=\frac{2}{1}$, *i.e.* a simple ratio.
- **Law of combining volumes :** The law discovered and proposed by the French chemist Joseph Louis Gay-Lussac (1778–1850) in the late 18th century is also called Gay Lussac's law of combining volumes. The law states that when gases react together to form other gases, and when all volumes are measured at the same temperature and pressure then the ratio between the volumes of the reactant gases and the gaseous products can be expressed in simple whole numbers. *For example in the reactions:*

  (i) $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

  1 vol. 3 vols. 2 vols.

  1 volume of nitrogen combines with 3 volumes of hydrogen to form 2 volumes of ammonia.

  (ii) $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$

  2 vols. 1 vol. 2 vols.

  2 volumes of hydrogen combine with 1 volume of oxygen to form 2 volumes of steam.

  (iii) $Cl_{2(g)} + H_{2(g)} \rightarrow 2HCl_{(g)}$

  1 vol. 1vol. 2vols
- 1 volume of chlorine gas combines with 1 volume of hydrogen to form 2 volumes of hydrogen chloride in gaseous state.

Dalton's Atomic theory : John Dalton, a British chemist and meteorologist, to justify the law of chemical combination postulated the simple theory of matter. Its basic postulates were:

- Elements are made of extremely small particles called atoms.

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- Atoms of a given element are identical in size, mass and other properties *i.e.* atoms of different elements differ in size, mass and other properties.
- Atoms cannot be subdivided, created or destroyed.
- Atoms of different elements combine with each other in a fixed, simple whole number ratios to form chemical compounds.
- In chemical reactions, atoms are combined, separated or rearranged. Atom is the smallest unit of matter that takes part in a chemical reaction.

Drawbacks of Dalton's Atomic theory : Dalton with his postulates failed to explain :

- Gay Lussac's law of the combining volume of gases.
- Why atoms of different elements differ in their properties and also why they combine together to form the molecules of compounds.
- The nature of force that holds the atoms together in a molecule.
- The ultimate particle of an element and that of a compound.

  An atom is not indivisible with electron, proton and neutron being the subatomic particles.
- The atoms of same elements called the Isotopes have different masses and therefore it's not an atom but a molecule which is the smallest chemical unit, capable of independent existence.
- **Berzelius hypothesis :** Jacob Berzelius, a Swedish chemist is considered, along with Robert Boyle, John Dalton and Antoine Lavoisier, to be one of the founders of modern chemistry. He studied and proposed that equal volumes of all the gases comprise an equal number of atoms under the similar conditions of temperature and pressure. When practised at the law of combining volumes, this hypothesis forecasts that the atoms are divisible and, hence, it is contrary to the hypothesis made by Dalton.
- **Avogadro's law :** In 1811, the Italian chemist Amedeo Avogadro proposed that "equal volumes of all gases at the same temperature and pressure contain the same number of molecules regardless of their chemical nature and physical properties". This number called Avogadro's number is 6.022×10^{23}. It is the number of molecules of any gas present in a volume of 22.41 L and is the same for the lightest gas (hydrogen) as for a heavy gas such as carbon dioxide or bromine. The law can be stated mathematically as V/n = k where *V* is the volume of the gas, *n* is the amount of the substance of the gas and *k* is a proportionality constant.
- The most important consequence of Avogadro's law is to realise that the ideal gas constant has the same value for all gases. when *p* is the pressure and *T* is the temperature of the gas.

  $$\frac{p_1.V_1}{T_1.n_1} = \frac{p_2.V_2}{T_2.n_1} = \text{constant}$$

  It has the same value for all gases, independent of the size or mass of the gas molecules.

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One mole of an ideal gas occupies 22.4 litre (dm^3) at STP, and occupies 24.45 litres at SATP (Standard Ambient Temperature and Pressure = 273K and 1 atm or 101.325 kPa). This volume is often referred to as the molar volume of an Ideal gas. Real gases may deviate from this value.

- **Mole :** The mole is the unit of measurement in the International System of Units (SI) for the amount of substance. It is defined as the amount of a chemical substance that contains as many elementary entities, e.g., atoms, molecules, ions, electrons, or photons, as there are atoms in 12 grams of carbon-12 (^{12}C), the isotope of carbon with relative atomic mass 12. This number is expressed by the Avogadro's constant(N_A), with value of 6.0221×10^{23} mol^{-1}. The mole is one of the base units of the SI, and has the unit symbol mol.
- **Atomic weight:** Atomic Weight is the average mass of atoms of an element, calculated using the relative abundance of Isotopes in a naturally occurring element. It is the weighted average of the masses of naturally occurring Isotopes i.e. its refers to the ratio of the average mass of the atoms of a chemical element to 1/12 of the mass of an atom of the isotope of carbon-12. It is also called relative atomic mass (A)

$$A = \frac{\text{Weight of one atom of an element}}{1/12^{th} \text{ part by weight of an atom of } C^{12} \text{ isotope}}$$

1amu = $1/12^{th}$ part by weight of an atom of C^{12} isotope

1amu = $1/N_A$ g = 1.66×10^{-24} g

- Therefore, absolute atomic weight = Atomic weight(A) x amu
- **Molecular weight :** Molecular weight is a measure of the sum of the atomic weight values of the atoms in a molecule *i.e.* it refers to the relative weight of a molecule of a compound with respect to amu weight, *i.e.*

$$B = \frac{\text{Weight of one molecule of a compound}}{1/12^{th} \text{ part by weight of an atom of C-12 isotope}}$$

- **Gram atomic and Gram molecular weight** : It refers to the weight of 1.0 mole of atoms,molecules or ions in a gram unit, *i.e.*

M = A amu x Avogadro's number

- Therefore, the gram molecular weight is numerically equal to molecular weight in gram unit with 1.0 mole of amu.
- **Empirical and molecular formula :** The empirical formula, also known as the simplest formula, represents the simplest possible ratio of atoms in the whole numbers of different elements present in a compound while the molecular formula is an expression of the number and type of atoms that are present in a single molecule of a substance. For example, the molecular formula of glucose is: $C_6H_{12}O_6$, *i.e.* one molecule of glucose contains 6 atoms of carbon, 12 atoms of hydrogen and 6 atoms of oxygen. If we simplify the numbers further then the empirical formula CH_2O will be different from the molecular formula. It simply represents that glucose has 2 moles of hydrogen for every mole of carbon and oxygen each.

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However, the glucose empirical formula is $C_3H_6O_3$ not CH_2O because of mass relations

For water, both empirical and molecular formulas are the same, *i.e.* H_2O.

Calculation of empirical and molecular formula : The calculation of the empirical and the molecular formula involves the following steps to be observed/performed in a sequential order:

- If you have mass then it is fine. If you have %, mass, assume total mass to be 100g so that % may become grams.
- Determine the mole of each element present.
- Determine the mole ratio by dividing all with the least value obtained.
- If the ratio is not in a whole number then multiply by 2,3 4,... to get an integer.
- Determine the mass of the empirical formula.
- Divide the molecular mass by the empirical mass to get a number.

$$n = \frac{\text{Molecular mass}}{\text{Empirical mass}}$$

- Multiply the empirical formula with the number to get the molecular formula.
- For example, if a compound with a molar mass of 34.0 g mol^{-1} is known to contain 5.88% hydrogen and 94.12% oxygen then

Element	Hydrogen	Oxygen
% by mass	5.88	94.12
Mass in grams	5.88 100× 100 = 5.88	100 = 94.12
Relative atomic mass in g	1.008	16.00
Moles = mass/ molar mass	5.88/1.008 = 5.83	94.12/16 = 5.88
Simplest ratio	5.83/5.83 =1	5.88/5.83 =1

Hence, empirical formula is H_1O_1(HO).

Molar mass of the empirical formula = 1.008 + 16.00 = 17.008 g mol^{-1}

Molar mass of compound = n *x* molar mass of empirical formula

34.0 = *n x* 17.008

n = 34.0 ÷ 17.008 = 2

Therefore, molecular formula of the compound is H_2O_2.

- **Concentration units:** There are a number of different ways for expressing solute concentration that are commonly used. Some of these are listed below:
- **Molarity (M) :** It refers to the moles of solute in one litre for solution, *i.e.*

Molarity = moles solute/litre of solution

Or n(moles of solute) = Molarity(M) x Volume(V)

If '*d*' g/cc is the density of a solution that contains *x* % of solute of molar mass M, its molarity

$$m = \frac{1000dx}{100M} \text{ or } = \frac{10dx}{M} = \frac{mol}{L} \text{ or mol } L^{-1}$$

CHEMISTRY

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Molality(m) : It refers to the number of moles of solute present in one kg of solvent. Molality is also called as molal concentration.

$$m = \frac{\text{Moles of solute (n)}}{\text{Weight of solvent in grams}} \; ; \; m = \frac{mol}{kg}$$

Normality (N) : It refers to the number of gram equivalents of solute in one litre of solution. Normality is also known as the equivalent concentration of a solution.

$$N = \frac{\text{Gram equivalent of solute}}{\text{Volume of solution in litre}}$$

- **Parts per million (ppm)** : This is a way of expressing very dilute concentrations of substances. One ppm is equivalent to 1 milli gram of something per litre of water (mg/L) or 1 milligram of per kilogram (mg/kg), The number of milligrams of solute per kg of solution = one ppm, since 1 mg = 10^{-3} g and 1 kg = 10^{3} g. Assuming the density of water is 1.00 g/mL, 1 litre of solution = 1 kg and hence, 1 mg/L = 1 ppm.
- This is generally true for fresh water and other dilute aqueous solutions. Parts per million concentrations are essentially mass ratios (solute to solution) x million (10^6).
- Some common mass ratios for solutions and solids are listed in the table given below:

Unit	Solution		Solid	
ppm	Mg/L	µg/mL	Mg/kg	µg/g
ppb	µg/L	ng/mL	µg/kg	ng/g
ppt	ng/L	pg/mL	ng/kg	pg/g

(ppm- parts per million, ppb- parts per billion, ppt- parts per trillion)

- **Mass per unit volume :** It refers to the density which is mass per unit volume. The SI unit is kilogram per cubic metre(kg/m^3). This means that finding the density of a particular object requires dividing its mass by its volume, mg/L = mass of solute/litre of solution.
- **Mole fraction, χ :** It is an another way of expressing the concentration of a solution. It is equal to the moles of one component divided by the total moles in the solution or mixture. Mole fraction is unitless expression. The mole fraction of all components of a solution, when added together, will euqal 1.

$$\text{Mole fraction } (\chi a) = \frac{\text{moles of a}}{\text{total moles}}$$

- where 'a' is the component that is being identified for mole fraction. It is used in a variety of calculations, but most notably for calculating partial pressures.

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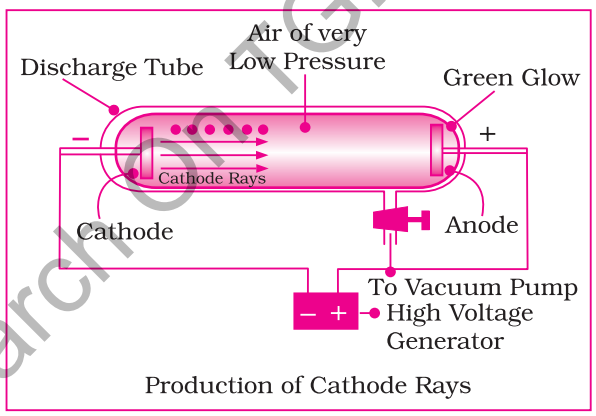
Chapter 2

STRUCTURE OF ATOM

Discovery and properties of electron , proton and neutron, Rutherford model of atom, limitation of the model, atomic and molecular weight, isotopes, isotones, isobars, Bohr's model of atom, emission spectrum of hydrogen atom, Heisenberg's uncertainty principle, Quantum numbers, electronic configuration , Hund's rule and Schrodinger's equation.

Cathode rays : J. J. Thomson constructed a glass tube which was partially evacuated, *i.e.* much of the air was pumped out of the tube. Then he applied a high electrical voltage between two electrodes at either end of the tube. He detected that a stream of particles (ray) came out from the negatively charged electrode (cathode) to the positively charged electrode (anode). He called this ray as cathode ray and the whole construction is called cathode ray tube.

These rays travel in straight lines. They are independent of the material composition of the cathode and on applying electric field in the path of cathode ray, they get deflected towards the positively charged plate. Hence, it showed that these rays consisted of negatively charged particles.



Production of Cathode Rays

➢ **Millikan Oil Drop Experiment:** In 1909, American physicist R. Millikan measured the charge of an electron using negatively charged oil droplets. The measured charge, (q) of an electron is equal to 1.6×10^{-19}C. Using the measured charge of electron, he calculated the mass of electron from e/m ratio given by J. J. Thomson's cathode ray experiment.

$e/m = -1.76 \times 10^{8}$ Coulomb, per gram

$m = e/ -1.76 \times 10^{8}$

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Putting e = -1.60×10^{-19} Coulomb,
m= 9.1×10^{-28} gram or 9.1×10^{-31}kg

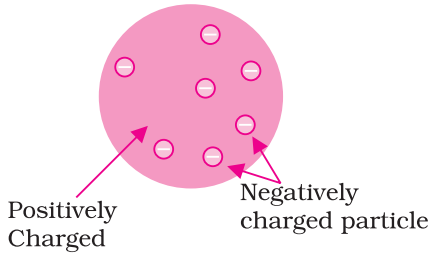
- **Proton :** The concept of a hydrogen like particle as a constituent of other atoms was developed over a long period. As early as 1815,William Prout proposed that all atoms are composed of hydrogen atoms (which he called "protyles"). In 1886, Eugen Goldstein discovered canal rays (anode rays) and showed that they were positively charged particles produced from gases. However, since particles from different gases had different values of charge to mass ratio (e/m), they could not be identified with a single particle, unlike the negative electrons discovered by J. J. Thomson. Later following the discovery of the atomic nucleus by Ernest Rutherford in 1911, in 1917 (in experiments reported in 1919), Rutherford proved that the hydrogen nucleus is present in other nuclei, a result usually described as the discovery of proton by Goldstein.
- **Neutron :** James Chadwick, determined that a neutral subatomic particle, the neutron, did exist and that its mass was about 0.1 percent more than that of a proton. He published his findings with characteristic modesty in a first paper entitled "Possible Existence of Neutron". In 1935, he received the Nobel Prize for his discovery of neutron.

Measured masses and charges of the three elementary particles

Particle	Symbol	Charge	Mass
Electron	e^-	-1.6×10^{-19}C	9.1×10^{-31}kg
Proton	$P^+(H^+)$	1.6×10^{-19} C	1.672×10^{-27}kg
Neutron	n^0	0.00C	1.674×10^{-27}kg

Thomson model of atom : J. J. Thomson, who discovered the electron in 1897, proposed the plum pudding model of the atom in 1904 before the discovery of the atomic nucleus in order to include the electron in the atomic model. According to his model, the atom is composed of electrons surrounded by a soup of positive charge to balance the electrons' (negative charges), like negatively charged "plums" surrounded by positively charged "pudding". However in 1904, Thomson's model was disapproved by Hans Geiger's and Ernest Marsden's 1909 gold foil experiment.

The Plum Pudding Model of an Atom



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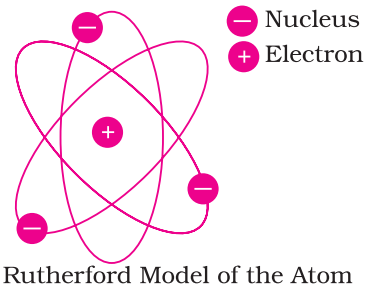
Rutherford's nuclear model of atom : Rutherford in his experiment, directed high-energy streams of α-particles from a radioactive source at a thin sheet (100 nm thickness) of gold. In order to study the deflection caused to the α-particles, he placed a fluorescent zinc sulphide screen around the thin gold foil. Rutherford made certain observations that contradicted Thomson's atomic model. These observations led him to conclude that:



Rutherford Model of the Atom

- Most of the space in an atom is empty as a major fraction of the α-particles bombarded passed through the foil without any deflection.
- The positive charge in an atom is concentrated in a very small volume as only some of the α-particles were deflected by the gold sheet that also by very small angles.
- The volume occupied by the positively charged particles in an atom is very small as compared to the total volume of an atom.

  Based on these observations, Rutherford proposed the atomic structure of an atom as :
- The positively charged particles and most of the mass of an atom is concentrated in an extremely small volume. He called this region of the atom as a nucleus.
- The negatively charged electrons surrounding the nucleus of an atom revolve around it with very high speed in circular paths called orbits.
- Electrons being negatively charged and nucleus being a densely concentrated mass of positively charged particles are held together by strong electrostatic force of attraction.
- **Limitations of Rutherford Model :** The major limitations were that he did not comment on the arrangement of the electrons around the nucleus, hence, he failed to explain the stability of an atom.
- **Atomic number :** The atomic number of a chemical element(also known as its proton number) is the number of protons present in the nucleus of an atom of that element. Therefore, atomic number is identical to the charge number of the nucleus. It is conventionally represented by the symbol Z that uniquely identifies a chemical element. In an uncharged atom, the atomic number is also equal to the number of electrons.

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- **Mass number :** It also called nucleon number which is represented by the symbol A. It refers to the sum of the nucleons, *i.e.* proton and neutron present in the nucleus of an atom, as listed below in the table:

Element	Symbol	Atomic number(Z) (no. of protons)	Mass number(A) (No.of protons + neutrons)	No. of neutrons
Nitrogen	N	7	14	14 – 7 = 7
Potassium	K	19	39	39 – 19 = 20
Cobalt	Co	27	59	59 – 27 = 32
Lead	Pb	82	207	207 – 82 = 125

- **Isotopes :** These are the atoms of an element with the same number of protons but that have different number of neutrons. Since the atomic number is equal to the number of protons and the atomic mass is the sum of protons and neutrons, isotopes are atoms with the same atomic number but different mass number, e.g., protium ($_1H^1$), deuterium ($_1H^2$) and tritium ($_1H^3$) are the three isotopes of hydrogen. Similarly, ($_6C^{12}$) and ($_6C^{14}$) are the two isotopes of carbon or ($_{17}Cl^{35}$) and $_{17}Cl^{37}$ of chlorine.
- **Stable v/s Radioactive isotopes:** Stable isotopes are isotopes with a stable combination of protons and neutrons, so that they have stable nuclei and do not undergo decay. These isotopes do not pose dangerous effects to living things, such as isotopes of carbon, potassium, calcium and vanadium. Radioactive isotopes have an unstable combination of protons and neutrons, so that they have unstable nuclei. Because these isotopes are unstable, they undergo decay, and in the process they emit alpha, beta and gamma rays. These isotopes pose dangerous effects to living organisms but if manipulated well, they can be used in food preservation, radio therapy in the treatment of cancer, etc.
- **Isobars :** These are the atoms of different elements having the same atomic mass but different atomic number. Since their number of electrons is different, their chemical properties are different but physically they are the same. The light nuclei have unstable isobars but heavy nuclei have stable isobars and these occur in pairs. If the number of protons of one isobar matches with that of another, they are called as mirror-nuclides of each other.

  Examples of isobars are $_{32}Ce^{76}$ and $_{34}Se^{76}$ and $_{26}Fe^{58}$ and $_{27}Ni^{58}$.
- **Isotones :** Any of two or more species of atoms or nuclei that have the same number of neutrons are called isotones. Thus, chlorine-37 and potassium-39 are isotones, because the nucleus of chlorine consists of 17 protons and 20 neutrons, whereas the

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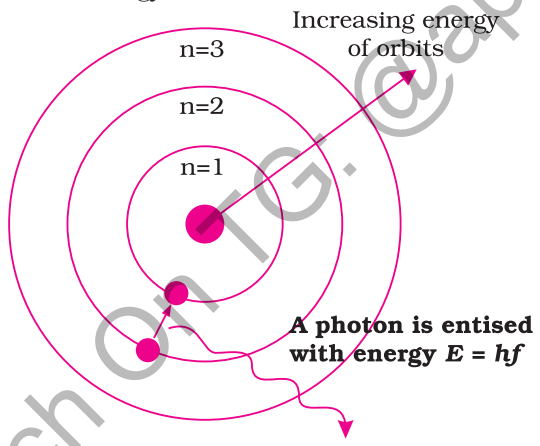
nucleus of potassium contains 19 protons and 20 neutrons. The ^{36}S, ^{37}Cl, ^{38}Ar, ^{39}K, and ^{40}Ca nuclei are all isotones of 20 because they all contain 20 neutrons.

- **Bohr's model of atom :** The experiments by Antonius Van den Broek and Niels Bohr refined the model of atom proposed by Rutherford.
- Van den Broek suggested that the atomic number of an element is very similar to its nuclear charge. Bohr proposed a Solar System-like model of the atom, where a nucleus contains the atomic number of positive charge and is surrounded by an equal number of electrons in orbital shells.

The important postulates of his model are:

- Electrons revolve round the nucleus with definite velocities in concentric circular orbits situated at definite distances from the nucleus. The energy of an electron in certain orbit remains constant. It neither emits nor absorbs energy. These are termed stationary states or main energy states.



- Bohr proposed that the angular momentum of an electron is quantized. Thus, the motion of an electron is restricted to those orbits where its angular momentum is an integral multiple of $h/2\pi$ where h is Planck's constant. (The value of 'h' is 6.626×10^{-34} J.s) Thus, we have the relationship $mvr = nh/2\pi$, where m is mass of electron, v is velocity of electron of the said orbit, r is the radius of that orbit, n is a simple integer.
- In addition, Bohr's model refined certain elements of the Rutherford model that were problematic particularly with respect to the unstability of an atom.
- The stationary states or allowed energy levels are only those where n = 1, 2, 3, ... They are also represented by letters K,L,M, O and P. This is known as Bohr quantum condition.
- The energy of an electron changes only when it moves from one orbit to another. An electronic transition from an inner orbit to outer

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orbit involves the absorption of energy. Similarly, when an electron jumps from an outer orbit to an inner orbit it releases energy in form of radiation, which is equal to the difference between the two energy levels.

- The energy released in the form of a radiation of a certain frequency appears in the form of a line in the atomic spectrum. If the energy of an electron in the outer orbit (n_2) is E_2 and energy of electron in the inner orbit (n_1) is E_1 then $E_2 - E_1 = \Delta E = h\upsilon$
- The value of n could be small integers 1, 2, 3 and these correspond to the first, second, third and so on. Quantum states are shells for the electron n is termed as the principal quantum number.
- **Valence electron v/s Core electron :** The electrons present within the outermost orbit that determlne the valence of an atom are called valence electrons while those present in inner orbits are called core electrons. Core electrons normally play no role in a chemical reaction.

Element	Atomic number	Core Electrons	Valence electron
Sodium	11	2, 8,	1
Calcium	20	2, 8, 8,	2
Aluminium	13	2, 8	3

- **Orbit v/s Orbital :** An orbital represents a space around the nucleus where there is maximum probability of finding an electron while an orbit is the well-defined circular path around the nucleus in which an electron revolves. An orbit can accommodate any number of electrons equal to $2n^2$ where n is the principle quantum number but an orbital can accommodate maximum of two electrons.
- **Electron's energy while orbiting around the nucleus:** Bohr proposed that an electron does not lose energy as long as it stays in the stationary orbit. It jumps to the higher stationary orbit only when supplied with energy from outside. When jumping to the lower orbit, it loses energy in the form of electromagnetic radiation. The energy change is accompanied by the absorption or loss of radiation energy of $E = E_2 - E_1 = h\upsilon$ where, h is a constant called 'Planck's constant', the frequency of radiation absorbed or emitted. (The absorption and emission of light due to electron jumps is measured by the use of spectrometers.)

Bohr's radius of stationary orbit: It is

$$r_n = \left(\frac{n^2}{z}\right) \times 0.529A^\circ$$

Where n is equal to number of shell.

Energy of stationary orbit: It is represented as

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$$E_n = \left(\frac{-KZ^2}{n^2}\right)$$

where K = 13.6eV or 2.18×10^{-18}J.

Speed of an electron in nth orbit : The speed of an electron in Bohr's n^{th} orbit is $V = \left(\frac{2.18 \times 10^6 Z}{n}\right)$ ms^{-1} where n is the number of Bohr's orbit.

Angular momentum of an electron: The angular momentum of an electron in Bohr's orbit is quantized.

$$mvr = \left(\frac{nh}{2\pi}\right)$$

where n= 1,2,3..... ∞

Centrifugal force of orbiting electron : The centrifugal force of orbiting electron is completely balanced by the electrostatic force of attraction between the nucleus and the electron, *i.e.*

$$\frac{mv^2}{r} = \frac{Ze^2}{4\pi r^2 \varepsilon_o}$$

Emission spectrum of hydrogen atom : The emission spectrum of atomic hydrogen is divided into a number of **spectral series**, with wavelengths given by the Rydberg formula:

$$\frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where R_H is Rydberg constant with value equal to 1.09678×10^7 m^{-1}.

These observed spectral lines are due to the electron making transitions between two energy levels in the atom. The classification of the series by the Rydberg formula was important in the development of quantum mechanics.

Lyman series : n_1 =1 , n_2= 2,3,4 .....It occurs in ultraviolet region.
Balmer series : n_1= 2 , n_2= 3,4,5.....It occurs in visible region.
Paschen series : n_1 =3, n_2= 4,5,6, ...It occurs in infra red region.
Brackett series : n_1 = 4, n_2= 5,6,7,.....It occurs in infra red region.
Pfund series : n_1 =5 , n_2= 6,7,.....It occurs in infra red region.

de-Broglie wave equation : The de Broglie equation is used for describing the wave properties of matter, specifically, the wave nature of the electron: $\lambda = h/mv$, where λ is wavelength, h is Planck's constant, m is the mass of a particle, moving at a velocity of v metre/sec. de Broglie suggested that particles in motion exhibit the properties of waves. Hence, Bohr is known to make a note on the dual nature of matter for first time.

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- **Relation between de-Broglie and Bohr's theory :** In a given stationary orbit with

$$2\pi r = n\lambda$$

- The number of de-Broglie wavelengths is equal to orbit number. If an electron at rest is accelerated by a potential difference of value V volt then the de-Broglie wavelength is $\lambda = \frac{h}{\sqrt{2mev}}$

  where h = Planck'sconstant, m is the mass and e is the charge of an electron.

- **Heisenberg's uncertainty principle :** It is a statement of the effects of wave-particle duality on the properties of subatomic objects. The uncertainty principle also called Indeterminacy Principle, articulated (1927) by the German physicist Werner Heisenberg. He stated that both the position and the velocity of an object cannot be measured exactly, at the same time, even in theory. The very concepts of exact position and exact velocity together, in fact, have no meaning in nature. Mathematically, we describe the uncertainty principle as follows :

$$\Delta x . \Delta p \geq \frac{h}{2\pi}$$

  where 'x' is the position, p is the momentum and h = Planck's constant.

- **Quantum numbers :** Each electron in an atom is described by a set of four different quantum numbers. The first three (n, l, m) specify the particular orbital of interest, and the fourth (m_s) specifies how many electrons can occupy that orbital.

- **Principal Quantum Number (n) :** n = 1, 2, 3, ...". It specifies the energy of an electron and the size of the orbital (the distance from the nucleus of the peak in a radial probability distribution plot). All orbitals that have the same value of n are said to be in the same shell. For a hydrogen atom with n=1, the electron is in its ground state; if the electron is in n=2 orbital, it represents an excited state. The total number of orbitals for a given n value is n^2.

- **Angular Momentum (Azimunthal) Quantum Number (l) :** l = 0, ..., n-1. It specifies the shape of an orbital with a particular principal quantum number. It divides the shells into smaller groups of orbitals called subshells. Usually, a letter code is used to identify l to avoid confusion with n:

l	0	1	2	3	4	5	...
Letter	*s*	*p*	*d*	*f*	*g*	*h*	...

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- The subshell with n=2 and l=1 is the 2p subshell if n=3 and l=0, it is the 3s subshell, and so on. The value of l also has a slight effect on the energy of the subshell the energy of the subshell increases with l ($s < p < d < f$).
- **Magnetic Quantum Number (ml) :** ml = -l, ..., 0, ..., +l. It specifies the orientation in space of an orbital of a given energy (n) and shape (l). This number divides the subshell into individual orbitals which hold the electrons. There are 2l+1 orbitals in each subshell. Thus, the 's' subshell has only one orbital, the p subshell has three orbitals, and so on.
- **Spin Quantum Number (ms) : ms = +½ or -½.** It specifies the orientation of the spin axis of an electron. An electron can spin in only one of two directions (sometimes called *up* and *down*).

Quantum Number		Symbols	Value	Significance
1.	Principal Quantum number	n	Integral value 1, 2, 3, 4 etc.	Indicates energy, distance of the eletrom from the nucleus and the size of the electron orbit
2.	Azimuthal Quantum number	l	Depend upon n, l = integral value from 0 to (n – 1).	Indicates the shape of electron orbit, namely circular or elliptical with diffrent ellipticity.
3.	Magnetic Quantum number	m	Depends upon, l, m = integral values from –l through 0 to + l	Indicates the orientation of electron orbit in space (con- cept of orbitals).
4.	Spin Quantum number	s	For each value of m, it is + ½ or –½	Indicates the spin of electron while moving about its own axis.

- **Pauli exclusion principle :** Wolfgang Pauli, (winner of Nobel Prize 1945), states that no two electrons in the same atom can have identical values for all four of their quantum numbers. It means that not more than two electrons can occupy the same orbital, and that two electrons in the same orbital must have opposite spins.

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Table of Allowed Quantum Numbers					
n	**l**	**m1**	**Number of orbitals**	**Orbital name**	**Number of electrons**
1	*0*	*0*	1	1s	2
2	*0*	*0*	*1*	2s	2
	1	–1,0,1	3	2p	6
3	0	0	1	3s	2
	1	–1,0,+1	3	3p	6
	2	–2,–1,0,+1,+2	5	3d	10
4	0	0	1	4s	2
	1	–1,0,+1	3	4p	6
	2	–2,–1,0,+1,+2	5	4d	10
	3	–3,-2,-1,0,+1,+2,+3	7	4f	14

- **Bohr-Bury Rules of Electronic (configuration) :** The distribuation of the electron in the different shells is called electronic configuration. Bohr and Bury proposed the following rules for this distribution :
  1. The maximum no. of electrons that can be accommodated in a shell is equal to $2n^2$

Shell	Quantum No. (n)	Maximum no of electron (2n2)
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$

  2. Electrons may go into a new outer shell once the inner shells are either completely or half filled.
  3. Electrons cannot jump between orbit unless they are accompanied with required energy chage.
- **Electronic configuration :** It is the representation of the arrangement of electrons (Afbau principle) in an atom distributed among the orbital shells and sub-shells. Commonly, it describes the orbitals of an atom in its ground state, but it can also be used for representing an atom that has been ionized into a cation or anion. Many of the physical and chemical properties of elements can be correlated to their unique electron configurations because the valence electrons are the determining factor for the unique chemistry of the element.
- **Hund's rule of maximum multiplicity**: The rule discovered was used to predict the ground state of an atom or molecule with one or more open electronic shells. The rule states that for a given electron

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configuration with the lowest energy term is the one with the greatest value of spin multiplicity, *i.e.* if two or more orbitals of equal energy are available, electrons will occupy them singly before filling them in pairs.

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f ...
6s 6p 6d ... ...

The completely filled orbitals are more stable than incompletely filled orbitals.

↑	↑	↑

Stable

↑↓	↑	

Unstable

The electronic configuration of Cr(24) and Cu(29) are the only two exceptions which do not occur w.r.t. this rule.

$Cr: 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5, 4s^1$ (not $3d^4, 4s^2$)

$Cu: 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^1$ (not $3d^9, 4s^2$)

- **Schrodinger's equation :** This equation is one of the greatest achievements of the 20th century as it shows all of the wave-like properties of matter. It is used for finding the allowed energy levels of quantum mechanical systems (such as atoms). The associated wave function gives the probability of finding the particle at a certain position. The solutions for bound systems give three quantum numbers, corresponding to three co-ordinates, and an approximate relativistic correction is possible by including the fourth spin quantum number.

For a single particle moving around in three dimensions, the equation can be written as :

$$\frac{ih}{2\pi}\cdot\frac{\partial\psi}{\partial t} = \frac{h^2}{8\rho^2 m}\cdot\left(\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}\right)+V\psi$$

- Here V is the potential energy of the particle (a function of x, y, z and (t) $i = \sqrt{-1}$, m is the mass of the particle and h is Planck's constant. The solution to this equation is the wave function $\psi(x, y, z, t)$.
- In some situations the potential energy does not depend on time t. In this case, we can often solve the problem by considering the simpler *time-independent* version of the Schrodinger wave equation for a function ψ depending only on space, *i.e.* $\psi = \psi(x, y, z)$:

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2 z}{\partial z^2}+\frac{8\rho^2 m}{h^2}(E - V)\psi = 0$$

where E is the total energy of the particle. The solution ψ to the full equation is then $\psi = \psi e^{-(2\pi iE/h)t}$.

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Chapter 3

Periodic Classification of Elements

CHEMISTRY

Dobereiner's traids, Newland's octave law, Mendeleev's periodic law and table, advantages and limitations of Mendeleev's periodic table, Modern Periodic law, long form of periodic table, valence and valence electrons, magic numbers, electronegativity, electron affinity, ionization energy, transition elements,lanthanides, actinides, transuranium elements, electropositive elements and electronegative elements.

- **Classification of elements :** To study and remember the properties of elements, the classification of elements has been done in such a way that similar elements are placed together while different elements have been separated from one another. Such a classification of similar elements together has resulted in the formulation of a periodic table.
- **Periodic table :** It refers to the arrangement of the 118 known elements according to their properties in the tabular form for an easy and effective understanding and learning of their properties.
- **Lavoisier and periodic classification :** Lavoisier in the 19th century had made the first attempt in classifying the elements as metals and non-metals.

Dobereiner's triads : Johann Dobereiner, a German scientist, in 1817 classified the elements in groups of three elements called triads. The elements in the triad had similar properties and the atomic weight of the middle member of each triad is close to the arithmetic mean of the other two elements. He had found only three such triads consisting of :

- lithium, sodium and potassium with atomic weights 7, 23 and 39 respectively.
- Calcium, strontium and barium with atomic weights 40, 88 and 137 respectively
- Chlorine, bromine and iodine with atomic weights 35.5, 80 and 127 respectively.
- The defect with Dobereiner's triad was that all the known elements that time could not be classified as triads. For example iron, manganese, nickel, cobalt, zinc and copper.
- **Newlands' law of octave :** John Newlands, an English chemist, in 1865 proposed a new system of classification. According to this new system, when the elements are arranged in the increasing order of atomic weights, the properties of every eighth element are similar to the first one. His proposed table was:

Element	Li	Be	B	C	N	O	F
Atomic Weight	7	9	11	12	14	16	19
Element	Na	Mg	Al	Si	P	S	Cl
Atomic Weight	23	24	27	29	31	32	35.5
Element	K	Ca					
Atomic Weight	39	40					

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Limitations of Newland's Law of octave

- This law was applicable only to lighter elements (up to atomic mass 40 i.e. only upto calcium).
- Newlands assumed that only 56 elements existed in nature.
- To fit the elements in his table, he adjusted two elements in the same slot such as cobalt and nickel while placed iron away from these two despite they have similar properties.

  The elements that were discovered later could not be adjusted into the octave pattern.
- **Mendeleev's periodic table** : The main credit of the periodic law goes to Dimitri Mendeleev and Lother Meyer who working independently proposed the same law. However, Mendeleev's system of classifying elements was more elaborate than Meyer's.
- **Mendeleev's periodic law :** According to this law, the physical and chemical properties of elements are periodic function of their atomic weights or atomic masses.

Contributions of Mendeleev's periodic table : The different contributions include:

- The table simplified the study of the chemistry of elements with the knowledge of the properties of seven groups in his table.
- The table has helped in correcting the atomic masses of some of elements based on their position in the table. The atomic masses of beryllium, gold, indium and platinum were corrected using the table.
- The table helped him predict the properties of the then three undiscovered elements, *i.e.* scandium (eka- boron), gallium (eka -aluminium) and germanium (eka-silicon). Later after their discovery, the properties were found to be almost similar to those predicted by Mendeleev.

At the time, when Mendeleev proposed his table, only 57 elements were known to the scientific world.

Defects in Mendeleev's periodic table : In spite of advantages, the table had some defects too such as :

- Position of hydrogen in group-1 or group-VIIA. It carries properties similar to both halogens and alkali metals, yet he placed it with alkali metals.
- Anomaly in the pairing of elements as in some cases increasing atomic masses were not observed to be the criteria of classification a such as in the placing of argon before potassium, or cobalt (58.93) before nickel (58.71) and tellurium.
- No separate position for isotopes as the isotopes of an element differ in their atomic masses.
- No separate position for lanthanides and actinides in the periodic table.
- **Modern periodic law :** In 1913 Moseley, an English physicist after studying relationship between X-ray spectra and atomic number of elements made him realize that the atomic number not atomic mass is to be the fundamental property of an element. The acceptance of

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the atomic number to be the important characteristic of an element, led to the modern periodic law which states that the physical and chemical properties of an element are the periodic functions of their atomic numbers. This law also led to the periodic arrangement of elements on the basis of their atomic number which led to the development of the modern long form of periodic table.

Important features of long form of periodic table : The important features of the long form of the periodic table that is based on the increasing atomic number of the elements, are:

- presence of vertical rows called groups and horizontal columns called periods. There are only two elements in the first period and 29 elements in the last seventh period instead of 32 elements. The other elements are yet to be discovered to fill up the empty spaces.
- presence of a total of 18 groups of which 1,2, 13, 14, 15, 16 , 17 and 18 has representative elements. The group -3 having transition elements has 12 sub-groups.
- no need for separate places for isotopes as they have the same atomic number.
- **Groups v/s periods : Groups**. The vertical columns in the Modern Periodic Table are called groups. There are 18 groups in the Modern Periodic Table.
- **Periods :** The horizontal rows in the Modern Periodic Table are called periods. There are 7 periods in the Modern Periodic Table.

Period No.	1	2	3	4	5	6	7
No. of elements	2	8	8	18	18	32	incomplete
Name of period	Very short	Short	Short	Long	Long	Very long	incomplete

- **Magic numbers :** The numbers 2,8,18 and 32 are called magic numbers because of periodicity occurring at regular intervals of 2,8,8,18,18 and 32 as listed in the table given below.

Period (n)	**Orbitals being filled up**	**Number of electrons, Number of elements in the period.**
First (1)	1s	2 = 2
Second (2)	2s 2p	2 + 6 = 8
Third (3)	3s 3p	2 + 6 = 8
Fourth (4)	4s 3d 4p	2 + 10 + 6 = 18
Fifth (5)	5s 4d 5p	2 + 10 + 6 = 18
Sixth (6)	6s 4f 5d 6p	2 + 14 + 10 + 6 = 32
Seventh (7)	7s 5f 6d 7p	2 + 14 + 10 + 6 = 32

- **Division of elements in the modern periodic table :** The different elements in the long form of periodic table have been divided into four main blocks called s, p, d and f block elements along with the noble gases as shown below.

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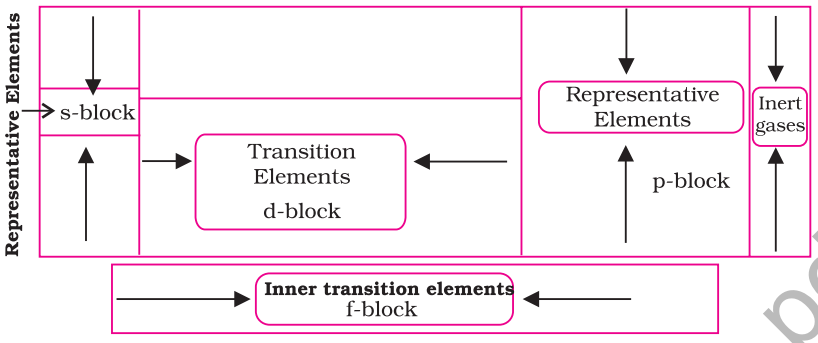
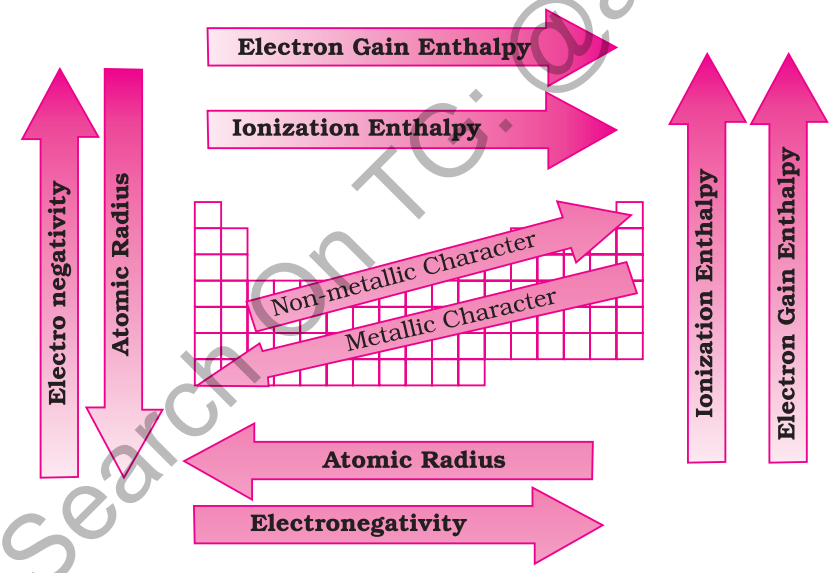
Modern Periodic Table



- **Elements and periodicity:** The recurrence of similar properties of the elements after certain regular intervals when they are arranged in order of increasing atomic numbers is called periodicity. This repetition is primarily because of the similar electronic configuration of atoms in the outermost energy shell (valence shell). Some of the observed trends are expressed below in tabulated form.



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Atomic radii : The atomic radius means the distance from the centre of the nucleus to the outermost shell carrying electron(s). If observed, atomic radius :

- Increases in the elements going down a group from top to bottom with increasing number of shells.
- Decreases across a period moving from left to the right of the periodic table until halogens with increasing number of the valence electrons. The increasing number of valence electrons increases the electrostatic force of attraction between them and the nucleus in the centre of an atom.

- The atom of a noble gas has larger atomic radius as compared to the atom of halogen belonging to the same period.
- **Isoelectronic ions :** These are ions of the different elements which have the same number of electrons such as each of N^{3-}, O^{2-}, Na^{1+}, Mg^{2+} and Al^{3+} has ten electrons.
- **Ionization enthalpy (energy):** It refers to the energy required to remove an electron from an isolated gaseous atom in ground state to form a cation It is measured in KJ mol^{-1}. With the reducing radius, the nuclear charge increases, hence, ionization enthalpy increases across a period while going down a group from top to bottom it decreases with increasing size and reducing nuclear charge.
- An isolated atom may lose one or more electron(s) the first ionization enthalpy is always less than the second one followed by the third one because of the increasing nuclear charge on the remaining number of valence electrons. $I.E_1 < I.E_2 < I.E_3$.
- **Electron gain enthalpy :** If an atom loses an electron, the other will be there to gain it. The energy change that an atom experiences when an electron is added to an isolated gaseous atom is called electron gain enthalpy. It increases when moving from left to right across a period while going down the group it decreases, *i.e.* in a group it increases coming from bottom to top of the group. Like ionization enthalpy it is measured in KJ mol^{-1}. It depends both on the size of the atom and the total nuclear charge.
- **Electronegativity :** It refers to the tendency of an atom of an element to attract the shared pair of electrons towards itself in a covalent bond. It generally increases on moving across a period from left to right because of the decrease in atomic radii and increase in the nuclear charge. When going down a group, it decreases with increasing size and reducing nuclear charge as the electron moves further away from the nucleus of an atom.
- **Metallic and non-metallic character :** In a periodic table, moving across a period from left to right, the metallic character decreases while the non-metallic character increases. However, in each period there does come an element that shows properties, some similar to metals and others to non metals. Such elements found in a zig-zag serial fashion are called metalloids. There is a total of eight of them. These include :

  Boron, silicon, germanium, arsenic, antimony, tellurium, pollonium and astatine.
- In a group moving from top to bottom, the metallic character increases.
- **Specific metals and non-metals :** Metals are normally solids except mercury. Gallium and cesium are also found in liquid state at room temperature because of their low melting points. If placed on a human palm, they melt into their respective liquid state.
- Bromine is a brownish colour liquid non-metal.
- Iodine in spite of being a non-metal possesses the metallic lustre.
- Metals sodium and potassium are kept stored in kerosene oil because of their high reactivity while the non-metal phosphorous is kept stored in cold water because of its low ignition temperature.

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- **Transition elements :** These include the elements that lie between the s-block and p-block elements. These are characterized by:
- presence of variable valence such as iron , it exists in two states Fe^{2+} and Fe^{3+}, similarly, copper exists in two states of Cu^{1+} and Cu^{2+}.
- formation of coloured salts except of zinc and cadmium.
- wide use of them or their salts as catalysts.
- **Inner transition elements :** The members of the f-block elements of lanthanide and actinide series are called inner transition elements. Each of the lanthanide and actinide has 14 elements. However, all the members of the actinide series are radioactive elements. Among lanthanide only one is a radioactive element. It is promethium.
- **Most electropositive element :** Cesium, the largest size atom with only one valence electron.
- **Most electronegative element :** Fluorine, the smallest size atom with seven valence electrons.
- **Halogens :** The members of the 17th group of the long form of periodic table are called halogens.
- **Alkali and Alkaline earth metals :** The first group of elements are called alkali metals and that of the second group are called alkaline earth metals.
- **Noble gases :** These gases also called inert gases belong to the 18th group, the last group of the periodic table. There are six of them: helium, argon, neon, krypton, xenon and radon. The only radioactive noble gas is radon found only in traces.
- **Transuranium elements :** These are elements with atomic numbes greater than that of uranium. They have been produced synthetically in laboratories by the fission of naturally found elements such as Americanum, Californium, etc.
- **Valency and Valence electrons :** The electrons present in the outermost shell of an atom are called valence electrons. Valency refers to the number of electrons lost or gained by an atom to complete its octet or duplet.

Valency of an element can be calculated from electronic configuration in two ways :

- Valency = number of valence electrons (if they are 1, 2, 3 or 4).
- Valency = 8 – number of valence electrons (if they are 5, 6, 7 or 8).
- **Electropositive elements v/s electronegative elements:** The elements which lose electrons and form positive ions are called electropositive elements. All the metals are electropositive in nature. This tendency to lose electrons by metals to form positive ions (cations) is called metallic character or electropositive character.
- The elements which gain electrons and form negative ions are called electronegative elements. All the non-metals are electronegative in nature. The tendency to gain electrons by non-metals to form negative ions (anions) is called non-metallic character or electronegative character.

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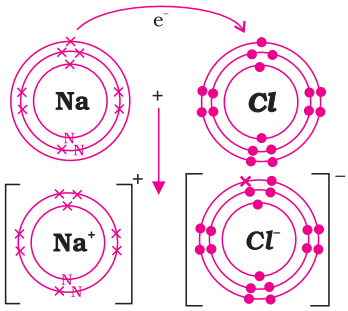
Chapter 4

Chemical Bonding And Molecular Structure

CHEMISTRY

Chemical bond , ionic bond, conditions favouring formation of ionic bond, covalent bonding, coordinate covalent bond , polar covalent bond, non-polar covalent bond, metallic bond, hydrogen bonding, characteristics of bonds, i.e. bond length, bond order, bond enthalpy, bond dissociation energy, VSEPR theory: postulates and limitations, molecular orbital theory, bonding and antibonding molecular orbitals ,sigma and pi bonds, hybridization: its type and shape of molecules.

- **Chemical bond :** It is a lasting attraction between atoms that enables the formation of chemical compounds. The bond may result from the electrostatic force of attraction between atoms with opposite charges, or through the sharing of electrons as in the covalent bonds. The strength of chemical bonds varies considerably. These bonds are "strong bonds" or weak bonds.
- **Strong bonds :** Covalent or ionic bonds.
- **Weak bonds :** Dipole-dipole interaction, the London dispersion force and hydrogen bonding.
- **Ionic bond :** It is formed by the attraction of oppositely charged atoms or groups of atoms. When an atom (or group of atoms) gains or loses one or more electrons, it forms an ion. Ions have either a net positive or net negative charge. Positively charged ions are attracted to the negatively charged 'cathode' in an electric field and are called cations. Anions are negatively charged ions named as a result of their attraction to the positive 'anode' in an electric field.
- In binary atomic system such as in NaCl, MgO, etc., Ionic bonding typically occurs between one metallic and other non-metallic atom. The electronegativity difference between the highly electronegative non-metal atom and the metal atom indicates the potential for the electron transfer. However, an ionic bond can also occur at the centre of a large covalently bonded molecule such as in enzymes, e.g., a metal atom like iron is both covalently bonded to large carbon groups and ionically bonded to simpler inorganic molecule like oxygen.



Ionic Bond

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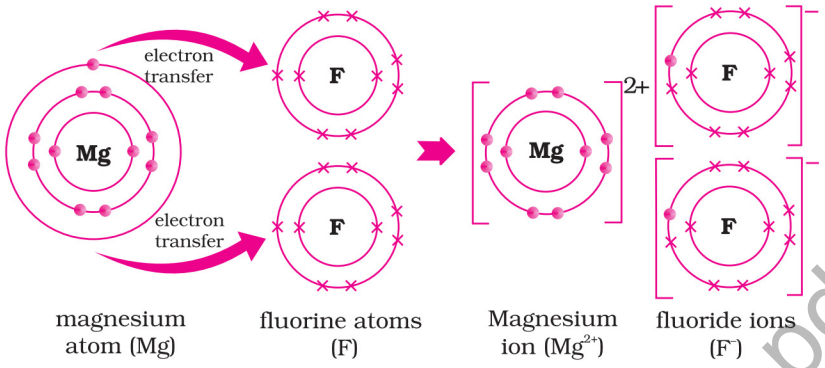

- Among organic functional groups, carboxylic acids (-COOH) contain carboxyl portion of the group bonded covalently act as anion to the acidic hydrogen ion (cation), e.g.,

$$\text{HCOOH} \quad \left[H : C : \overset{\overset{O}{\cdot\cdot}}{O} : H \right]$$

Factors affecting the ionic bond formation : There are a number of factors that favour the formation of ionic bond such as:

- **Ionization enthalpy :** The lower is the ionization enthalpy, *i.e.* energy, the greater is the tendency of forming ionic bond.

$$M_{(g)} \rightarrow M^+_{(g)} + e^- \text{ Ionization enthalpy}$$

- **Electron gain enthalpy :** The greater is the value of negative electron gain enthalpy, the greater is the ease in forming anion, *i.e.* ionic bond.

$$X_{(g)} + e^- \rightarrow X^-_{(g)} \qquad \text{(Electron gain enthalpy)}$$

- **Lattice enthalpy :** With the increasing lattice enthalpy, the ease of the formation of ionic bond also increases simultaneously.

$$M^+_{(g)} + X^-_{(g)} \rightarrow MX \qquad \text{(Lattice enthalpy)}$$

- **Covalent bonds :** These chemical bonds involve the sharing of a pair of valence electrons by two atoms, in contrast to the transfer of electrons in ionic bonds. Such bonds lead to stable molecules if they share electrons in such a way as to create a noble gas configuration for each atom.
- Hydrogen gas forms the simplest covalent bond in the diatomic hydrogen molecule. Nitrogen and oxygen which make up the bulk of the atmosphere also exhibit covalent bonding in forming their diatomic molecules. The halogens such as chlorine also exist as diatomic gases by forming covalent bonds.

In covalent bonding, depending on the sharing of the number of electrons, the bond formed can be single, double or triple as shown below.

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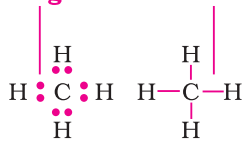
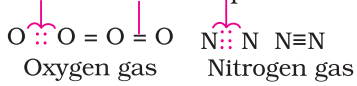
Single covalent bond

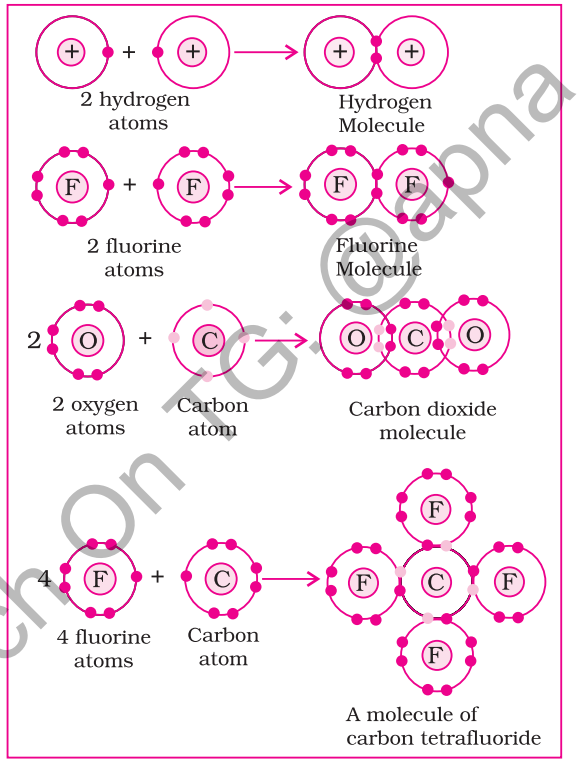


Methane

Double bond Triple bond



Oxygen gas Nitrogen gas



➢ **Octet rule:** The noble gas valence shell configuration of elements is the most stable configuration. It is ns^2, np^6 which is also called as octet configuration. All elements tend to get octet configuration either by the sharing of electrons or by the complete transfer of electrons. The complete transfer of valence electrons leads to the formation of ions that are involved in ionic or electrovalent bonding whereas the equal sharing of electrons results in the formation of covalent bonds.

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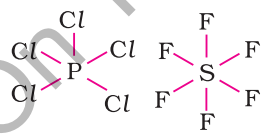
- However, there are exceptions to the octet rule.
- **Two electrons :** The main exception to the rule is hydrogen, which is at its lowest energy when it has two electrons in its valence shell. Helium (He) is similar in respect that it, too, only has room for two electrons in its only one valence shell.
- Lithium, with three protons and electrons, is the most stable when it gives up an electron.
- **Less than an Octet :** Aluminium and boron are other notable exceptions, they can function well with six valence electrons. In BF_3,the boron shares its three electrons with three fluorine atoms. The fluorine atoms follow the octet rule, but boron has only six electrons. Although atoms with less than an octet may be stable yet they will usually attempt to form a fourth bond to get eight electrons. BF_3 is stable, but it will form BF_4^- when possible.

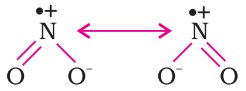
  Most elements to the left of the carbon group have so few valence electrons that they are in the same situation as boron, they are electron-deficient. Electron deficient elements often show metallic rather than covalent bonding.
- **More than an Octet :** In Period 3, the elements on the right side of the periodic table have empty d orbitals. The d orbitals may accept electrons, allowing elements like sulphur and phosphorus to have more than an octet. Compounds such as PCl_5 and SF_6 have 10 and 12 electrons around their central atoms, respectively.



Xenon hexafluoride uses d-electrons to form more than an octet.

This compound shows another exception being a noble gas compound.

Odd Numbers : Some elements, notably nitrogen, have an odd number of electrons and will form somewhat stable compounds. Nitric oxide has the formula NO in which nitrogen cannot have an octet. It will have seven electrons instead. A molecule with an unpaired electron is called a *free radical* and radicals are highly reactive. They are so reactive that many of them only exist for a fraction of a second. As radicals, both NO and NO_2 are actually remarkably stable. At low temperatures NO_2 does react with itself to form N_2O_4, its *dimer*, that is not a radical.



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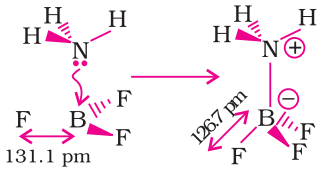
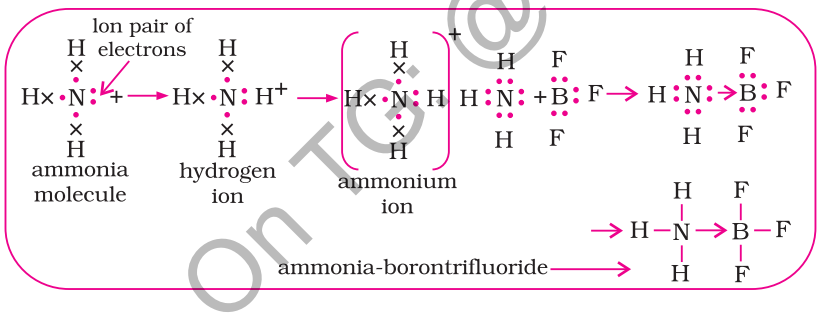
Nitrogen dioxide has an unpaired electron. (Note the positive charge above the N).

Coordinate covalent bond : It is also called a dative bond. It is a kind of 2-centre, 2-electron covalent bond in which the two electrons are derived from the same atom. The bonding of metal ions to ligands involves this kind of interaction.



The formation of an adduct of ammonia and boron trifluoride, involves the formation of a coordinate covalent bond. In all metallic aqua complexes $[M(H_2O)_n]^{x+}$, the bonding between water and the metal cation is a coordinate covalent bond. Metal-ligand interaction in most organometallic compounds and most coordination compounds is coordinate covalent bonding.



- **Polar and non-polar covalent bonds :** Depending upon the nature of the atoms which combine with each other by the mutual sharing of electrons, two types of covalent bonds are formed :
- **Non-polar covalent bond :** This type of bond is formed between the two atoms of the same element. Atoms of the same element attract electrons equally. So, when a covalent bond is formed between the two atoms of same element, the electrons are shared equally between the two atoms, *i.e.* the shared electron-pair lies exactly midway between the two atoms. This type of bond is formed in the molecules such as H_2, O_2 and Cl_2, etc.
- **Polar covalent bond :** This type of bond is formed between two atoms of different elements. The shared pair of electrons does not lie exactly midway between the two atoms, it lies more towards the atom which is more electronegative. The atom with higher affinity for electrons develops a slight negative charge and the atom with lesser affinity for electrons a slight positive charge.

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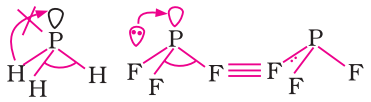
- In the hydrogen chloride (HCl) molecule, hydrogen and chlorine atoms are bonded through electrons sharing.The shared pair of electrons lies more towards Cl atom (because Cl is more electronegative). Therefore, Cl atom acquires a slight negative charge (-δ) and H atom, a slight positive charge (+δ).
- The O-H bond in water (H_2O) is also a polar bond. The hydrogen atom has a slight positive charge, and the oxygen atom has the slight negative charge, i.e. ($H^{+\delta}$–$O^{-\delta}$). The compounds having polar covalent bonds undergo ionization when dissolved in any polar solvent, such as water. Such polar compounds in solutions produce free ions. For example, when hydrogen chloride (HCl) is dissolved in water, it ionizes to produce $(H_3O)^+$ (hydronium ion) and Cl– (chloride ion).

  $H_2O - H^{+\delta} \rightarrow H_2O.....H^{+\delta}.....Cl^{-\delta} \rightarrow H_3O^+ + Cl^-$
- **Bond length :** It refers to the average distance between the nuclei of two bonded atoms in a molecule. It is a transferable property of a bond between the atoms of fixed types, relatively independent of the rest of the molecule.
- Bond length is related to bond, order *i.e.* when more electrons participate in bond formation, the bond is shorter. Bond length is also inversely related to bond strength and the bond dissociation energy. With all other things being equal, a stronger bond is shorter. In a bond between two identical atoms, half the bond distance is equal to the covalent radius.

  N ≡ N < N = N < N – N (Bond length decreases with increasing multiplicity of bond between atoms)

  C – C < Si – Si < Ge- Ge (Bond length increases with increase in the sizes of atoms)
- Bond lengths are measured in the solid phase by means of X-ray diffraction, or approximated in the gas phase by microwave spectroscopy.
- **Bond angle :** It refers to the average angle between the orbitals of the central atom containing the bonding electron pairs in the molecule. The unit of bond angle is either degree or minute or second. This gives an idea about the distribution of the orbital around central atom in a molecule. Therefore, bond angle determines the shape of a molecule, e.g., the H-O-H bond angle in H_2O is 104.5° and H-N-H bond angle in NH_3 is 107°.



Bond Angle 93.8° 97.8°

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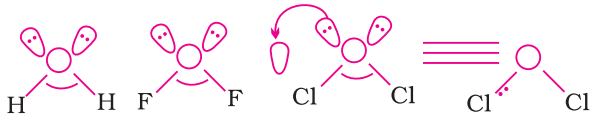

Bond Angle 104.5° 103.2° 110.8°

- **Bond enthalpy :** Bond energy is defined as the amount of energy required to break one mole of the stated bond. For example, the bond energy of a O-H single bond is 463 kJ/mol, *i.e.* it requires 463 kJ of energy to break one mole of O-H bonds. Similarly,

$O_2\ [O = O]_{(g)} \qquad O_{(g)} + O_{(g)} \qquad \Delta_a H^o = 498.0\ Kj.mol^{-1}$

$N_2\ [N \equiv N]_{(g)} \qquad N_{(g)} + N_{(g)} \qquad \Delta_a H^o = 946.0\ Kj.mol^{-1}$

In order to break any bond, energy must be absorbed. Therefore, bond breaking is always an endothermic change ($\Delta H > 0$). Conversely, energy is always released upon the formation of a bond. Therefore, bond making is always an exothermic change ($\Delta H < 0$).

- **Bond order :** It refers to the number of chemical bonds between a pair of atoms. For example, in diatomic nitrogen Na ≡ N the bond order is 3, in acetylene H – C ≡ C – H the bond order between the two carbon atoms is also 3, and the C – H bond order is 1. Bond order gives an indication of the stability of a bond. The element with bond order value 0 cannot exist but compounds can have a '0' bond value. Isoelectric species have same bond number. In molecules that have resonance or non classical bonding, bond order does not need to be an integer. Ex: benzene has bond order 1.5.

In molecular orbital theory, bond order is also defined as half the difference between the number of bonding electrons and the number of antibonding electrons as per the equation below. This often but not always yields the same result. Bond order is also an index of bond strength and is also used extensively in valence bond theory.

$$\text{Bond order} = \frac{\text{Number of bonding electrons} - \text{Number of antibonding electrons}}{2}$$

Or

$$\text{Bond order} = \frac{Nb - Na}{2}$$

- Generally, the higher the bond order, the stronger is the bond, *i.e.* it acts as the index of bond strength.
- **Resonance :** It also called mesomerism is a way of describing delocalized electrons within certain molecules or polyatomic

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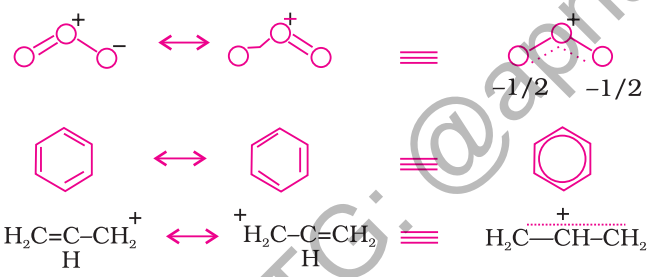
ions where the bonding cannot be expressed by one single Lewis structure. A molecule or ion with such delocalized electrons is represented by several contributing structures called resonance structures or canonical structures.

- Each contributing structure can be represented by a Lewis structure, with only an integer number of covalent bonds between each pair of atoms within the structure. Several Lewis structures are used collectively to describe the actual molecular structure, which is an approximate intermediate between the canonical forms called a resonance hybrid. Contributing structures differ only in the position of electrons, not in the position of nuclei. The difference between the potential energy of the actual structure and that of the contributing structure with the lowest potential energy is called the resonance energy or delocalization energy.



For resonance each contributing structure should:

- have same atomic positions.
- have same number of unpaired electrons.
- have same or nearly same energy.
- not have the like charges residing on the adjacent atoms.

Electronegativity and chemical bonding:

- Electronegativity is defined as the ability of an atom in a particular molecule to attract electrons to itself (the greater the value, the greater the attractiveness for electrons). Hence, it shows the function of;
  - the atom's ionization energy (how strongly the atom holds on to its own electrons)
  - the atom's electron affinity (how strongly the atom attracts other electrons). It is used for determining the nature and type of bond, i.e. non-polar covalent, polar covalent or ionic.

For example, an element with large (negative) electron affinity and high ionization energy (always endothermic, or positive for neutral atoms) will attract electrons from other atoms and resist having its own electrons attracted away such an atom will be highly electronegative.

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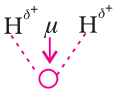
Fluorine is the most electronegative element (electronegativity = 4.0); the least electronegative element is cesium which is the most electropositive element.

Electronegativity value and type of bond : If the difference in electronegativities of two atoms is

- equal to zero with the values being equal, the bond is non-polar covalent
- greater than 0, but less than 2.0, the bond is polar covalent
- 2.0, or greater, the bond is ionic.
- **Dipole Moment :** When two electrical charges, of opposite sign and equal magnitude, or atoms in covalent bond are separated by a distance, a dipole is established. The size of a dipole is measured by its dipole moment. Dipole moment is measured in Debye units, which is equal to the distance between the charges multiplied by the charge (1 Debye equals 3.34×10^{-30}cm).

  While considering a bond dipole within a molecule

  ½ diatomic = Q × r 

- This bond dipole is interpreted as the dipole from a charge separation over a distance r between the partial charges Q^+ and θ^- ($\delta^+ - \delta^-$) the orientation of the dipole is along the axis of the bond.
- Consider a simple system of a single electron and a proton separated by a fixed distance. When a proton and an electron are close together, the dipole moment (degree of polarity) decreases. However, as a proton and an electron get farther apart, the dipole moment increases. In this case, the dipole moment is calculated as :

  $$\grave{i}=Qr=(1.60\times10^{-19}\ C).(1.00\times10^{-10}\ m)=1.60\times10^{-29}\ cm.$$

- The Debye characterizes the size of dipole moment. When a proton & an electron are 100 pm apart, the dipole moment is 4.80D:

  $$\grave{i}=(1.60\times10^{-29}\ \text{Å}"m)1D/3.336\times10^{-30}C\text{Å}"\ \text{or}\ m=4.80D$$

4.80D is a key reference value and represents a pure charge of +1 and -1 separated by 100 pm.

The measurement of dipole moment helps distinguish between polar and non-polar molecules. Non-polar molecules have zero dipole moment while polar molecules have non-zero value of dipole moment.

- The greater the electronegativity difference between the atom's, the more is the value of dipole moment. Therefore, the dipole moment of hydrogen halides decreases with the decreasing electronegativity of halogen atom.
- **Polyatomic molecules:** In these molecules, the dipole moment not only depends upon the individual dipole moments of the bonds but

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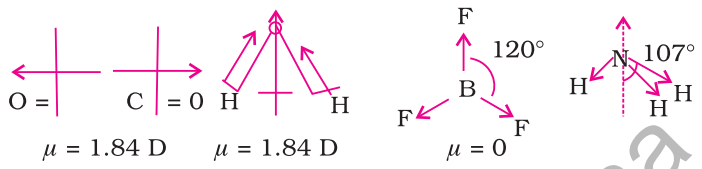
also on the spatial arrangement of various bonds in the molecule. In such molecules, the dipole moment of the molecule is the vector sum of the dipole moments of various bonds.

- For example, both carbon dioxide (CO_2) and water (H_2O) are triatomic molecules but the dipole moment of carbon dioxide is zero being a linear molecule whereas that of water is 1.84 D.
- In tetra-atomic molecules such as BF_3 and NH_3, the dipole moment of BF_3 molecule is zero while that of NH_3 is 1.49 D.



- **Metallic bond :** It's the force that holds atoms together in a metallic substance. These solids consist of closely packed atoms. In most cases, the outermost electron shell of each of the metal atoms overlaps with a large number of neighbouring atoms so that the valence electrons continually may move from one atom to another. Hence, they are not associated with any specific pair of atoms. These valence electrons in metals, unlike those in covalently bonded substances, are non-localized, capable of wandering relatively free throughout the entire crystal.
- The atoms that the electrons leave behind become positive ions, and the interaction between such ions and valence electrons gives rise to the cohesive or binding force that holds the metallic crystal together. Many of the characteristic properties of metals are attributable to the non-localized character of the valence electrons.
- For example, this condition is responsible for the high electrical and thermal conductivity of metals, malleability, ductility and prevention of their fracturing when stretched or hammered. When a metal is shaped or drawn, it does not fracture, because the ions in its crystal structure are quite easily displaced with respect to one another. Moreover, the non-localized valence electrons act as a buffer between the ions of like charge and thereby prevent them from coming together and generating strong repulsive forces that can cause the crystal to fracture.
- **Hydrogen bonding :** A hydrogen bond is the electromagnetic attraction between polar molecules in which hydrogen is bound to a larger atom, such as oxygen or nitrogen. This is not a sharing of electrons, as in a covalent bond.
- Hydrogen bond is an attraction between the positive and negative poles of charged atoms. It is usually stronger than normal dipole

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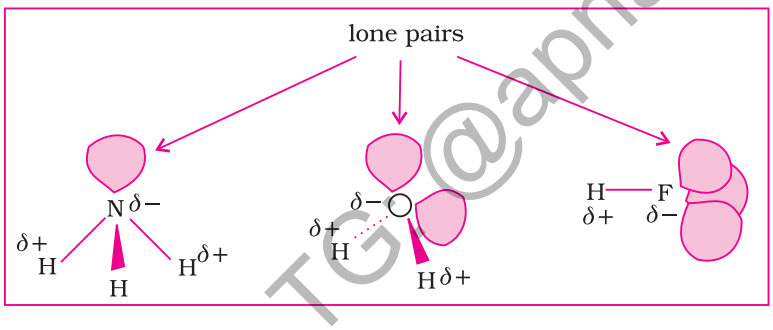
forces between molecules but not nearly as strong as normal covalent bonds within a molecule. It is only about 1/10 as strong as a covalent bond.

- Each water molecule can potentially form four hydrogen bonds with surrounding water molecules. There are exactly right numbers of δ^+ hydrogen and lone pairs so that each one of them may be involved in hydrogen bonding. This is why the boiling point of water is higher than that of ammonia or hydrogen fluoride.

In each of the molecules shown below :

- hydrogen is attached directly to one of the most electronegative elements, causing the hydrogen to acquire a significant amount of positive charge.
- each of the elements to which hydrogen is attached is not only significantly negative but also has at least one 'active' lone pair.



Hydrogen bonding in water is responsible for its anomalous character with its density being maximum at 4°C and ice , its solid form being less denser than liquid water.

VSEPR (Valence Shell Electron Pair Repulsion) bond theory : The basic concept of the theory was suggested by Sidgwick and Powell (1940) to provide useful idea for predicting shapes and geometries of molecules. It was later developed by Gilepespie and Nyholm as a theory with main postulates being:

- For polyatomic molecules containing three or more atoms, one of the atoms of that molecule is called the central atom to which all the other atoms are linked.
- The shape of a molecule depends upon the total number of valence shell electron pairs.
- The electron pairs tend to occupy positions in space such that the electronic repulsion gets minimized and hence, the distance between them is maximized.
- The valence shell is assumed to be a sphere so that the electron pairs may localize on the surface of the sphere with maximum distance between the valence shell and electron pairs.

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- If the central atom is surrounded by bond pairs then we can expect a symmetrical shape to the molecule and if surrounded by both lone pairs and bond pairs then develop a distorted shape of the molecule.
- In case of resonating structures, this theory can be applied to any of them.
- The order of repulsion between electron pairs follows the trend:

  lone pair – lone pair > lone pair – bond pair > bond pair – bond pair (lp – lp > lp – bp > bp – bp)

  Limitations of VSEPR theory : It has failed to explain
- Isoelectronic species, i.e. the elements having the same number of electrons such as Sc^{+3}, Ca^{+2}, K^{+1}, Ar, Cl^{-1}, S^{-2}, P^{-3} and Mg^{2+} , N^{3-}, O^{2-}, F^{-}.
- These species can differ in the shape even if they have the same number of electrons.
- the transition metal compound as it failed to guess the structure of certain compounds. The reason being that it did not take the associated sizes of the substituents and inactive lone pairs into account.

Molecular orbital theory : It was proposed by Hund and Mulliken in 1932 to explain the formation of chemical bonds and behaviour of molecules such as relative bond length, solubility, paramagnetic or diamagnetic behaviour, etc. Its major postulates are:

- Atomic orbitals of comparable energy and proper symmetry combine together to form molecular orbitals.
- The movement of electrons in a molecular orbital is influenced by all the nuclei of combining atoms, i.e. molecular orbital is polycentric in nature.
- The number of molecular orbitals formed is equal to the number of combining atomic orbitals. When two atomic orbitals (AO's) combine together, two molecular orbitals (MO's) are formed. One molecular orbital possesses higher energy than corresponding atomic orbitals and is called anti-bonding molecular orbital (ABMO) and the other has lower energy and is called bonding molecular orbital (BMO).
- In molecules electrons are present in molecular orbitals. The electron filling is in accordance with Pauli's exclusion principle, Aufbau principle and Hund's rule.

  Atomic orbital v/s molecular orbital : In atomic orbital, an electron is under the influence of only one positive nucleus; therefore, it has simple shapes but in molecular orbital, an electron is under the influence of two or more nuclei and, therefore, has complex shapes.

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Bonding molecular orbital v/s Anti-bonding molecular orbital

Bonding molecular orbital with greater electron density in the region between the nuclei of bonded atoms is formed by the addition of the overlapping of atomic orbitals ($\Psi MO) = \Psi_A + \Psi_B$) but anti-bonding molecular orbital with lesser electron density in the region between the nuclei of bonded atoms is formed by the subtraction of the overlapping of atomic orbitals ($\Psi(MO) = \Psi_A - \Psi_B$). However, BMO possesses lesser energy than isolated atomic orbitals as compared to ABMO that possesses more energy than isolated atomic orbitals.

Rules for filling molecular orbitals : The following three rules have to be followed for filling molecular orbitals:

- **Aufbau principle :** According to this, the molecular orbital with the lowest energy is filled first.
- **Pauli's exculsion principle :** It states that each molecular orbital can accommodate maximum of two electrons having opposite spins.
- **Hund's rule :** It states that if there are two molecular orbitals of the same energy, the pairing of electrons will occur only after each orbital of same energy has one electron.
- **Stability of a molecule :** The stability of a molecule depends on the number of electrons in the bonding and anti-bonding molecular orbital. If N_b is the number of electrons in bonding orbital and N_a is the number of electrons in antibonding orbitals then if

  (i) $N_b > N_a$: — stable.

  (ii) $N_b < N_a$ *or* $N_b = N_a$:— unstable

Hybridization : It refers to the phenomenon of mixing up of atomic orbitals of similar energies and formation of equivalent number of entirely new orbitals of identical shape and energy. The newly formed orbitals are called "hybrid orbitals". During hybridization:

- The number of hybrid orbitals generated is equal to the number of pure atomic orbitals that participate in hybridization process.
- There is no application for isolated atoms. It only explains the bonding scheme in a molecule. Covalent bonds in polyatomic molecules are formed by the overlap of hybrid orbitals or of hybrid orbitals with unhybridized ones.
- **sp-hybridization :** It involves the combination of one s and one p-orbitals to form two hybrid orbitals of equal energy, e.g., in BeF_2 molecule, the sp-hybridized orbitals of Be overlap with the half-filled orbitals of two fluorine atoms to give a linear shape.
- **sp^2 -hybridization:** It involves the combination of one s and two p-orbitals to form three hybrid orbitals of equal energy, e.g., in BF_3 molecule; the sp^2 hybridized orbitals are oriented at an angle of 120°. When three sp^2 hybridized orbitals of B overlap with three p-orbitals of fluorine, three π -bonds are formed with bond angle 120°. The shape of BF_3 molecule is thus trigonal planar .

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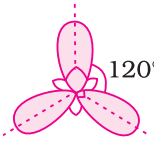
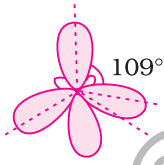
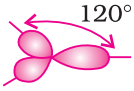
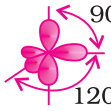
Types of hybridiz-ation	Atomic orbitals involved	Representing direction of hybrid orbitals formed along with bond angles	Examples
sp	One s + One p	180° Linear	B_eCl_2, B_eH_2, C_2H_2
sp^2	One s + two p	 120° Triangular planar	BF_2, NCl_3, C_2H_2, CO_3^-
sp^3	One s + Three p	 109°28 Tetrahedral	CH_4, CCl_4, NH_2^-

- **sp^3-hybridization :** It involves the combination of one s and three p-orbitals to form four hybrid orbitals of equal energy, e.g., methane (CH_4) molecule. The sp^3-hybridized orbitals are oriented at an angle of 109°28'. When these four sp^3 hybrid orbitals overlap with four 1s orbitals of hydrogen, a symmetrical tetrahedral shaped CH_4 molecule is formed.
- **sp^3d-hybridization :** It involves the combination of one s, three p and one d-orbitals to form five hybrid orbitals of equal energy, e.g., PCl_5 molecule.

Hybridization	Setric	Shape, with angles number
sp	2	Linear 180°
sp^2	3	Trigonal Planar  120°
sp^3	4	Tetrahedral 109.5°
sp^3d	5	Trigonal Bipyramidal  90° 120°

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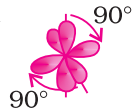
sp^3d^2	6	Octahedral 

- **sp^3d2-hybridization :** It involves the combination of one s, three p and two d-orbitals to form six hybrid orbitals of equal energy, e.g., SF_6 molecule.

Hybridization	Formula	Number	Shape angle	Bond	Bonding
sp	AX_2	2	Linear	180^0	1 single bond/lone pair and two double bonds
sp^2	AX_3	3	Trigonal planar	120^0	2 single bonds/lone pairs and one double bond
sp^2	AX_2N		Bent	120	
sp^3	AX_4	4	Tetrahedral	109.5^0	4 single bonds/ lone pairs at $109^0 28'$to each other.
sp^3	AX_2N_2		Bent	109.5^0	
sp^3	AX_3N		Trigonal Pyramidal	109.5^0	
sp^3d	AX_5	5	Triangular Bipyramidal	$120^0 90'$	5 single bonds/lone pairs
sp^3d^2	AX_6	6	Octahedral	90^0	6 single bonds/ lone pairs

- **sigma bonds** (**σ bonds**) : These are the strongest type of covalent chemical bonds formed by head-on overlapping between atomic orbitals as shown in the figure given below.
- **Sigma bond rule** : It states that the number of sigma bonds in a molecule is equivalent to the number of atoms plus the number of rings minus one.

$$N_\sigma = N_{atoms} + N_{rings} - 1$$

- A molecule with no rings can be represented as a tree with a number of bonds equal to the number of atoms minus one such as in dihydrogen, H_2, with only one sigma bond, or ammonia, NH_3, with 3 sigma bonds. There is no more than 1 sigma bond between any two atoms.

(a)

(σ) Sigma bond

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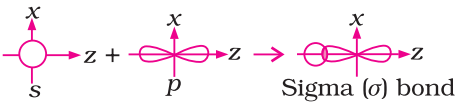
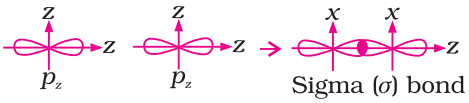
(b) 

(c) 

Formation of a sigma bond due to

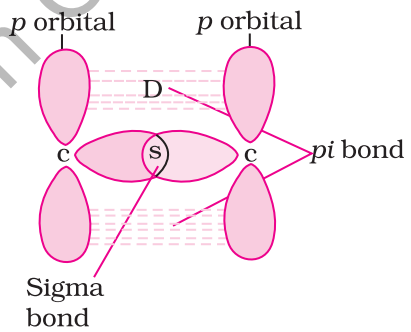
(a) The *s*-*s* overlap

(b) The *s*-*p* overlap

(c) The p_z-p_z overlap

Molecules with rings have additional sigma bonds, such as benzene rings, which have 6 C-C sigma bonds within the ring for 6 carbon atoms. The anthracene molecule, $C_{14}H_{10}$, has three rings so that the rule gives the number of sigma bonds as 24 + 3 –1 = 26. In this case there are 16 C – C sigma bonds and 10 C – H bonds.

- pi (π) bonds : These are covalent chemical bonds where two lobes of one involved atomic orbital overlap two lobes of other involved atomic orbital. Each of these is zero at a shared nodal plane, passing through the two bonded nuclei. The same plane is also a nodal plane for the molecular orbital of the pi bond.
- **Pi bonds are usually weaker than sigma bonds :** The (–C=C–) double bond has bond energy less than twice the C-C single bond energy. Pi bonds result from the overlap of atomic orbitals that are in contact through two areas of overlap.
- **Pi-bonds are more diffuse bonds than the sigma bonds :** Molecular fragments joined by a pi bond cannot rotate about that bond without breaking the pi bond, because rotation involves destroying the parallel orientation of the constituent p orbitals.



- A single bond contains one sigma bond (direct head-on overlap of orbitals).
- A double bond contains one sigma bond and one pi bond (side-on overlap of p orbitals)
- A triple bond contains one sigma bond and 2 pi bonds.

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Chapter 5

States & Properties of Matter : Solids, Liquids And Gases

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Relative strength of different forces, dipole –dipole forces , Kessom forces, dipole-induced dipole forces, postulates of kinetic theory of gases, Boyle's law, Charle's law, Dalton's law of partial pressure, Combined gas law, Maxwell-Boltzmann distribution of molecular velocities, related speed expressions, Ideal gas v/s real gas, liquefication of gas, enthalpy of evaporation, evaporation v/s boiling and vapour pressure curve.

- **States of matter :** There are three general possible states of matter because of the difference in intermolecular force of attraction and hence, intermolecular distance , the two being inversely proportional to each other. The three possible states of matter are solids, liquids & gases.
- **Intermolecular forces :** These are weak forces present in ionic, polar and non-polar molecules. The study of these forces and their effect was first studied on real gases by Dutch scientist, Johannes van der Waals. Hence, these forces end being called as van der Waal's forces. These forces arise because of
- dispersion forces also called London forces
- dipole-dipole forces also called Keesom forces
- dipole-induced dipole forces
- hydrogen bonding.

Relative strength of the attractive van der Waals forces as compared to Ionic or Covalent bond.

Relative Bond Strengths	
Ionic (or Covalent) bonds	1000
Hydrogen bonds	100
Dipole - Dipole	10
Dipole - Induced Dipole	5
London Forces	1

Dipole-dipole interactions : The dipole-dipole interactions occur when :

- the partial charges formed within one molecule are attracted to an opposite partial charge in a nearby molecule.
- polar molecules align so that the positive end of one molecule may interact with the negative end of another molecule.
- when there are unlike covalent bonds between atoms within a molecule (intramolecular bonding), dipole-dipole interactions create attractions between molecules of a substance (intermolecular attractions).

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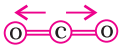
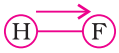
Example : Carbon dioxide (CO_2) & Hydrogen flouride (HF)

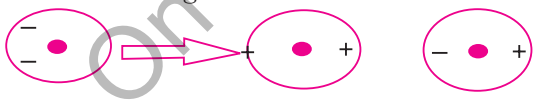


Here the more electronegative oxygen atoms pulls electron density towards themselves. But the vector sum of the dipoles between atoms is zero.

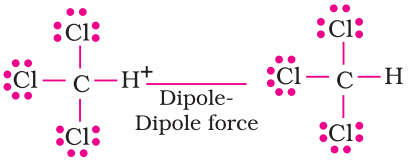


In HF, there is no opposing dipole moment to cancel out. So, molecular dipole does result.

- **London forces :** These forces are the weakest intermolecular , temporary attractive forces that result when the electrons in two adjacent atoms occupy positions that make the atoms form temporary dipoles. Hence, they are also called "Instantaneous dipoles" forces or induced dipole attraction. These attractive forces cause non-polar substances to condense into liquids and to freeze into solids when the temperature is lowered sufficiently.
- An atom or a molecule can develop a temporary (instantaneous) dipole when its electrons are distributed unsymmetrically during the course of their revolution about the nucleus. A second atom or molecule, polar or non-polar, in turn, can be distorted by the appearance of the temporary dipole in the first atom or molecule (because electrons repel one another) which leads to an electrostatic attraction between the two atoms or molecules.
- Dispersion forces are present between any two molecules when they are almost touching.



Uneven distribution of electrons in He | Instantaneous dipole | Induced dipole on neighbouring He



London dispersion forces tend to be :

- stronger between molecules that are easily polarized.
- weaker between molecules that are not easily polarized.
- **Dipole-Dipole Attractions :** Dipole–dipole interactions are a type of intermolecular attraction between two molecules. Dipole-dipole interactions are electrostatic attraction between the permanent dipoles of different molecules. These interactions align the molecules to increase the attraction.

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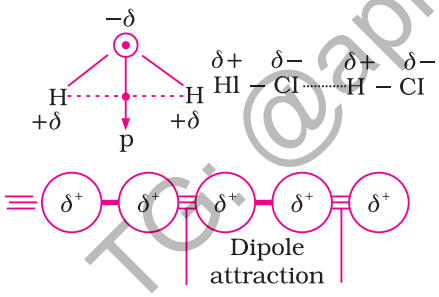
- An electric monopole is a single charge, while a dipole consists two opposite charges closely spaced to each other. The molecules that contain dipoles are called polar molecules. They are very abundant in nature. For example, a water molecule (H_2O) has a large permanent electric dipole moment. Its positive and negative charges are not centered at the same point, it behaves like few equal and opposite charges separated by a small distance. These dipole-dipole attractions give water many of its properties, including its high surface tension.
- Another example of a dipole–dipole interaction is in hydrogen chloride (HCl) where the relatively positive end of a polar molecule attracts the relatively negative end of another HCl molecule. In H*cl* the interaction between the two dipoles is an attraction rather than full bond because it does not involve any sharing of electrons between the two molecules.



- **Dipole – induced dipole forces :** A dipole-induced dipole attraction is a weak attraction that results when a polar molecule induces a dipole in an atom or in a non-polar molecule by disturbing the arrangement of electrons in the non-polar species. This type of attractive forces operates between the polar molecules having permanent dipole and the molecules lacking permanent dipole. Permanent dipole of the polar molecule induces dipole on the electrically neutral molecule by deforming its electronic cloud. Thus, an induced dipole is developed in the other molecule. The induced dipole moment depends upon the dipole moment present in the permanent dipole and the polarisability of the electrically neutral molecule.
- The induced dipole forces appear from the induction which is the attractive interaction between a permanent multipole on one molecule with an induced multipole on another. One example of an induction-interaction between permanent dipole and induced dipole is the interaction between HCl and Ar.

  An example of a dipole-induced dipole force between water (H_2O) and xenon (Inert gas).

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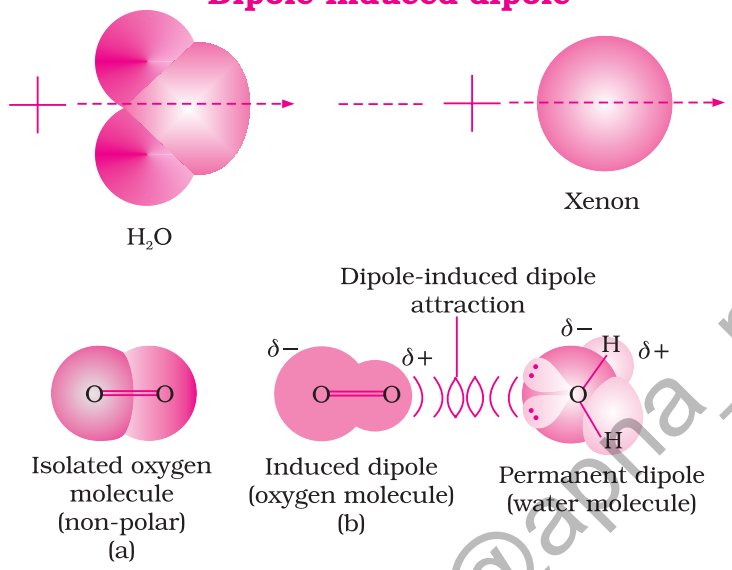
Dipole-induced dipole



Hydrogen Bond: Hydrogen bond is the electrostatic attraction between two polar groups that occurs when a hydrogen atom is covalently bond to a highly electronegative atom such as Nitrogen, Oxygen, Flourine experience the electrostatic field of another highly electronegative atom nearby.

This is stronger that van der Waal interaction, but weaker than covalent or ionic bonds.

General properties of gases: There are three principal properties that characterize the gaseous state of matter:

- **Compressibility :** Gases are easy to compress into liquid at low temperature and high pressure.(Liquefication)
- **Expandability :** Gases expand to completely fill their containers. In gases particles are the least ordered than in liquids or solids, the gaseous form of the same substance occupies much more space, than that of solids and liquids.
- All pure substances display similar behaviour in the gaseous phase. At 0° C and 1 atmosphere of pressure, one mole of every gas occupies 22.4 litres of volume. Molar volumes of solids and liquids, on the other hand, vary greatly from one substance to another. In a gas at 1 atmosphere, the molecules are approximately 10 diameters or less apart. Unlike liquids or solids, gases occupy their containers uniformly and completely.

For gases, the

- mass is measured in terms of molar mass,

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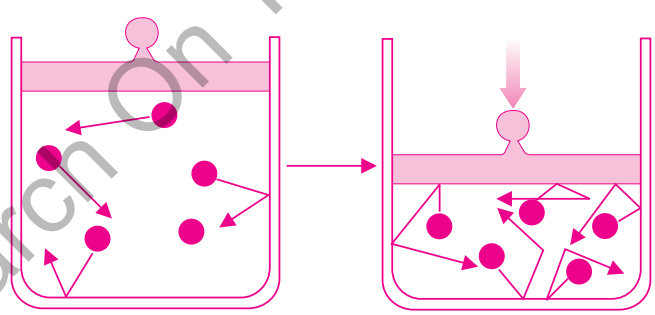
- volume in terms of cm^3: $1m^3 = 10^3 dm^3 = 10^6 cm^3$; $1L = 10^3 cm^3 = 1dm^3 = 10^{-3} m^3$)
- pressure is measured in terms of atm, 1atm= 760mm Hg = 760 torr
  1 atm= 1.01325 bar = 1.01325 x 10^5 P or 1 bar = 0.987atm.

Postulates of kinetic theory of gases : The main postulates include :

- The molecules in a gas are small and very far apart. Most of the volume, a gas occupies is empty space.
- Gas molecules are always in state of constant random motion.
- Molecules can collide with one another and with the walls of the container. Collisions with the walls account for the pressure exerted by the gas on the walls of container.
- When collisions occur, the molecules loose no kinetic energy, i.e. the collisions are said to be perfectly elastic. The total kinetic energy of all the molecules remains constant unless there is some outside interference with the surrounding.
- The molecules exert no attractive or repulsive forces on one another except during the process of collision and in between collisions; they move in straight lines.
- Boyle's law : Also called as Boyle–Mariotte law, or Mariotte's law), it is an experimental gas law that describes how the pressure of a gas tends to increase or decrease with change in the volume of a gas. It states that, " The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system."

Decreasing volume increases collisions and increases pressure



V_1 = 1.0L
P_1 = 100 mm Hg

V_2 = 0.5 L
P_2 = 200 mm Hg

- Mathematically, Boyle's law can be stated as $P \propto 1/V$ or $PV = K$ where P is the pressure of the gas, V is the volume of the gas, and K is a constant.
- The equation states that the product of pressure and volume is a constant for a given mass of confined gas as long as the temperature is constant. For comparing the same substance under two different sets of conditions, the law can be usefully expressed as

$$P_1V_1 = P_2V_2$$

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Problem : A gas occupies a volume of 250mL at 745 mmHg and 298 K. Find the additional pressure required to reduce the volume to 200 mL at same temperature.

Solution : $P_1 = 745$ mm Hg $\quad P_2 = ?$

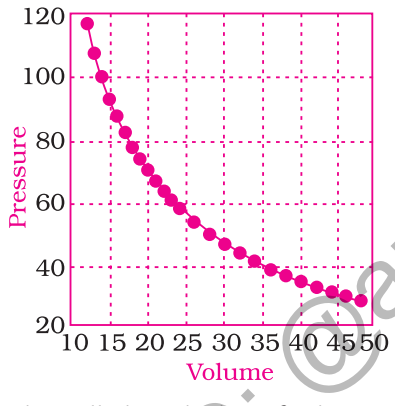
$V_1 = 250mL \quad V_2 = 200mL$

With $T_1 = T_2$, $P_1V_1 = P_2V_2$

$745mm\ Hg \times 250mL = P_2 \times 200mL$

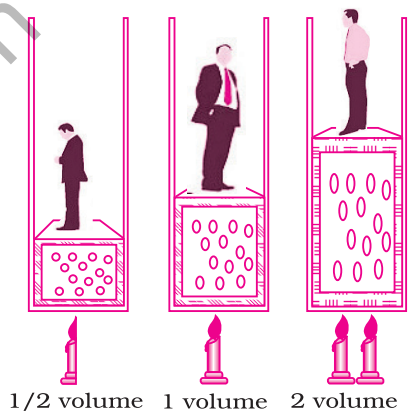
$P_2 = 745mm\ Hg \times 250mL/200mL = 931.25mm\ Hg$

Additional pressure required = 931.23 – 745 = 186.25mm Hg



➢ **Charle's law :** Also called as the law of volumes is an experimental gas law that describes how gases tend to expand when heated. The law states that when the pressure on a sample of a dry gas is held constant, the Kelvin temperature and the volume are directly proportional to each other, *i.e.* $V \propto T$ or V/T = Constant,

where V is the volume of the gas, T is the temperature of the gas (measured in Kelvin) and K is a constant.



The law describes how a gas expands as the temperature increases. conversely, a decrease in temperature will lead to a decrease in

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volume. For comparing the same substance under two different sets of conditions, the law can be written as: $V_1T_2 = V_2T_1$

The equation shows that, as absolute temperature increases, the volume of the gas also increases in proportion.

Problem : Find the increase in volume of gas when the temperature of 800mL of air increases from 27^0C to 47^0C at constant pressure of 1 bar.

Solution : $V_1 = 800mL$ $V_2 = ?$

$T_1 = 27^0C = 273 + 27 = 300K$

$T_2 = 47^0C = 273 + 47 = 320K$

With $P_1 = P_2$, $V_1T_2 = V_2T_1$

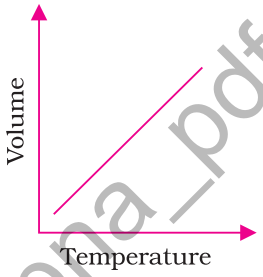
$800mL \times 320K = V_2 \times 300K$

$V_2 = 800mL \times 320K / 300K$

$= 853.3mL$

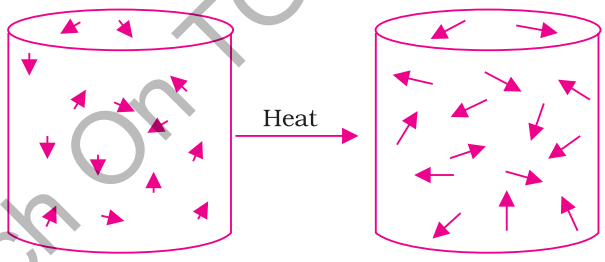
Increase in volume = 853.3 – 800

=53.3mL

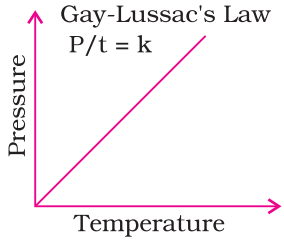


➢ **Gay-Lussac's law :** It describes the relationship between pressure (*P*) and temperature (*T*) when the volume remains constant. As the temperature increases, the pressure also increases or pressure remains proportional to temperature when the volume is kept constant.

$$P/T = kg \text{ or } P_1/T_1 = P_2/T_2$$



Pressure-temperature for gases. As the temperature increases, the gas particles have greater kinetic energy (longer arrows) and collisions are more frequent and forceful



Problem : A 20L cylinder containing 6 atm of gas at 27°C. What would the pressure of the gas be if the gas was heated to 77°C.?

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Solution :

P_1 = 6 atm; T_1 = 27°C = 27 + 273 k = 300k

P_2 = ?; T_2 = 77°C = 77 + 273k = 350k

$P_1/T_1 = P_2/T_2 = P_2 = \frac{P_1T_2}{T_1} = \frac{(6atm)(350k)}{300k}$

P2 = 7atm

When Boyle's law, Charles' law, and Gay-Lussac's law are put together, one comes up with the combined gas law, which states that:

- Pressure is inversely proportional to volume, or higher volume equals lower pressure.
- Pressure is directly proportional to temperature, or higher temperature equals higher pressure.
- Volume is directly proportional to temperature, or higher temperature equals higher volume.

Hence, according to combined gas law, $PV / T = k$. It shows how pressure, volume and temperature are related to one another, where k is a constant number.

Combined Gas Law

Law	Variables Held Constant	Relationship	Equation
Boyle's	T,n	Inverse	$P_1V_1=P_2V_2$
Charles'	P,n	Direct	$\frac{V_1}{T_1}=\frac{V_2}{T_2}$
Gay-Lussac's	V,n	Direct	$\frac{P_1}{T_1}=\frac{P_2}{T_2}$
Combined gas law	n	n/a	$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$

where 'n' is number of moles of the gas present.

Problem : 450mL of a gas occupies a container that has a temperature of 27°C and a pressure of 788 mm Hg. What is the temperature if the volume is reduced to 50mL at 760 mm Hg?

Solution : P_1 = 788mm Hg V_1= 450mL

T_1= 28°C = (273 + 27) =300K

P_2 = 760mm Hg V_2= 50mL

T_2=?

$P_1V_1/T_1 = P_2V_2/T_2$

788mm Hg x 450mL/300K = 760mm Hg x 50mL/T_2

T_2 =(760mmHg x 50mL x300K)/788mm Hg x 450mL

T_2 = 32.15K or -240.85°C

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Gas equation : According to Boyle's law,for a fixed mass of a gas at constant temperature $V \propto 1/P$ (Constant T and n)

According to Charle's law $V \propto T$ (constant P and n)

According to Avogadro's law $V \propto n$ (Constant P and V)

Thus, by combining the above three equations

$$V \propto nT/P$$

Or $$PV \propto nT$$

$$PV = nRT$$

- R is the constant of proportionality called molar gas constant or universal gas constant. Its value varies with the units in which pressure and volume are expressed.

For one mole of gas (n=1) ,PV = RT

- at STP, when pressure is expressed in atm and volume in litre , $R = 0.0821\ L\ atm\ K^{-1}\ mol^{-1}$
- when pressure is measured in atm and volume in mL, $R = 82.1\ atm\ mL\ K^{-1}\ mol^{-1}$
- when pressure is measured in Pascal(Pa) and volume in m^3, $R = 8.314\ J\ mol^{-1}K^{-1}$
- when pressure is measured in bar and volume in dm^3, $R = 0.0831\ bar\ dm^3\ mol^{-1}K^{-1}$

Problem : Calculate the number of moles of hydrogen present in 500mL sample of hydrogen at a pressure of 1 bar and 27^0C.

Solution : According to ideal gas equation , pV =nRT or n = pV/RT

$P = 1\ bar$ $V = 500mL = 500 \times 10^{-3}dm^3$

$T = 27^0C = (273 + 27)= 300K$ $R = 0.083\ bar\ dm^3K^{-1}mol^{-1}$

$n = 1bar \times 500 \times 10^{-3}dm^3 / 0.083\ bar\ dm^3K^{-1}mol^{-1} \times 300K$

$= 0.0201\ mol = 2.01 \times 10^{-2}mol.$

Dalton's law of Partial pressure : English chemist John Dalton (1766-1844) reasoned that the low density and high compressibility of gases are indicative of the fact that they consist mostly of empty space. From this, one can conclude that when two or more different gases occupy the same volume, they behave entirely independent of one another.

Dalton's Law (Dalton's Law of Partial Pressures) states that the total pressure exerted by the mixture of non-reactive gases is equal to the sum of the partial pressures of individual gas that does not react with one another. Mathematically, this can be stated as follows :

$$P_{total} = P_1 + P_2 + P_3 + \ldots\ldots\ldots\ldots + Pn$$

where P_1, P_2 and P_n represent the partial pressures of each gas.

Problem : A 2.0 L container is pressurized with 0.25 atm of oxygen gas and 0.60 atm of nitrogen gas. What is the total pressure

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inside the container?

Solution: $P_{total} = P_{oxygen} + P_{nitrogen}$

With $P_{oxygen} = 0.25atm$ and $P_{nitrogen} = 0.60atm$

$P_{Total} = 0.25 + 0.60 = 0.85atm$

The total pressure inside the container is 0.85 atm.

- **Mole Fraction :** It's a way of expressing the relative proportion of one particular gas within a mixture of gases. This can be obtained by dividing the number of moles of a particular gas '*i*' by the total number of moles in the mixture:

$$x = \frac{\text{Number of moles of i}}{\text{Total number moles of gas}}$$

- **Partial pressure in terms of mole fraction:** Let three gases at temperature T, enclosed in volume V exert partial pressure P_1, P_2 and P_3 respectively. Then

$$P_1 = \frac{n_1RT}{V},\ P_2 = \frac{n_2RT}{V},\ P_3 = \frac{n_3RT}{V}$$

$$P_{Total} = P_1 + P_2 + P_3 = \frac{n_1RT}{V} + \frac{n_2RT}{V} + \frac{n_3RT}{V}$$

$$= (n_1 + n_2 + n_3)\frac{RT}{V} = \frac{nRT}{V}$$

With $x_1 = n_1/n$, $P_1 = x_1 \times P_{Total}$

Problem : A gaseous mixture containing 1.79 mol of nitrogen and 0.31 mol of oxygen was enclosed in a vessel of 10L capacity at 27°C. Calculate the partial pressure of each gas and the total pressure of the mixture of gases.

Solution : $pV = nRT$, $p = nRT/V$

$P_{Total} = 4.40 + 0.67 = 5.16atm.$

- **Maxwell – Boltzmann distribution of molecular speeds:** Ludwig Boltzmann and James Clerk Maxwell contributed to the science of statistical thermodynamics in which one can examine the properties of very large numbers of molecules.
- The distribution of molecular velocities in equilibrium is given by the Maxwell-Boltzmann equation:

$$f(V) = 4pv^2\left(\frac{m}{2pk_BT}\right)^{3/2} e^{-mv^2/2k_BT} \qquad (1.2)$$

where m is the mass of the molecule, v is the magnitude of the velocity, T is absolute temperature, and k_B is the Boltzmann constant. The fraction of molecules with velocities between any two values v_1 to v_2 is equal to the area under the curve between the two velocities

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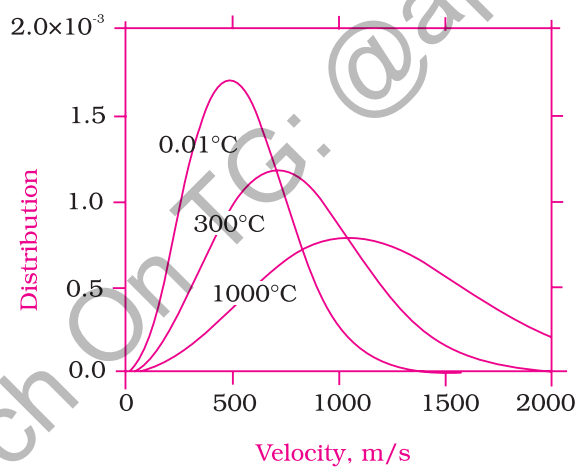
(the total area under the curve is 1). The velocity v_{max} corresponds to the maximum of the distribution, the mean velocity and the mean of the square of the velocity are all given in terms of temperature:

$$V_{max} = \left(\frac{2k_BT}{m}\right)^{1/2}, \ \overline{V} = \left(\frac{8k_BT}{\rho m}\right)^{\frac{1}{2}}, \ \overline{V^2} = \frac{3k_BT}{m}$$

The Maxwell-Boltzmann distribution is a result of remarkable generality. It is independent of pressure and applies to any material, regardless of composition or phase as shown in the figure. It shows this distribution for water at three temperatures. At the triple point, the solid, liquid and vapour, all have the same distribution of velocities.

The properties of liquids depend on both temperature and pressure, but the effect of pressure is generally weak. Molecules in a liquid (or in a solid) phase are fairly closely packed so that increasing pressure may do little to change molecular distances by any appreciable amount. As a result, most properties of liquids are quite insensitive to pressure and can be approximately taken to be the functions of temperature only.



Maxwell-Boltzmann distribution of molecular velocities in water

➢ **Related Speed Expressions :** Three speed expressions can be derived from the Maxwell-Boltzmann distribution. The most probable speed, the average speed, and the root-mean-square speed. The most probable speed is the maximum value on the distribution plot. This is established by finding the velocity when the following derivative is zero

$$C_{mp} = \sqrt{2RT / M}$$

The average speed is the sum of the speeds of all the molecules divided by the number of molecules.

$$C_{avg} = \sqrt{8RT / \rho M}$$

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The root-mean-square speed is the square root of the average speed-squared.

$$C_{rms} = \sqrt{3RT / M}$$

where R is the gas constant, T is the absolute temperature and M is the molar mass of the gas.

It *always* follows that for gases that follow the Maxwell-Boltzmann distribution (if thermallized)

$$C_{mp} < C_{avg} < C_{rms}$$

➢ **Real gas v/s Ideal gas :** A real gas differs from an ideal gas in number of ways as listed below.

	Real gas	Ideal gas
1.	It obeys gas laws only under low pressure and high temperature conditions.	It obeys gas laws under all conditions of the pressure and temperature.
2.	Volume of molecules is not negligible to the volume of gas.	Volume occupied by molecules is negligible to the total volume.
3.	It obeys van der Waal's equation, *i.e.* $[p+(an^2/V^2)(V-nb) = nRT$	It obeys ideal gas equation, *i.e.* $pV = nRT$
4.	The force of attraction among molecules is not negligible at all pressure and temperature.	The force of attraction among molecules is negligible at all pressure and temperature.

➢ **Liquefication of gases :** The physical state of matter primarily depends on the intermolecular force of attraction, hence, the intermolecular distance. Any possible change brought in the intermolecular distance will change the state of matter. In gases when the pressure is increased or temperature is reduced or both happen simultaneously, the intermolecular distance decreases forcing the gas to get liquefied. As studied by Thomas Andrews in 1869, the lowering of temperature is more effective as compared to the increasing of pressure. The maximum temperature at which a gas remains in liquid state is called its critical temperature. Any slightest rise of the temperature above critical temperature, transforms the given liquefied gas into its gaseous state.

➢ Critical pressure of a gas is defined as the minimum pressure required to liquefy a gas at its critical temperature while critical volume of a liquefied gas is the volume occupied by a mole of gas at its critical temperature and pressure. The critical constants of the common gases are listed in the table given below:

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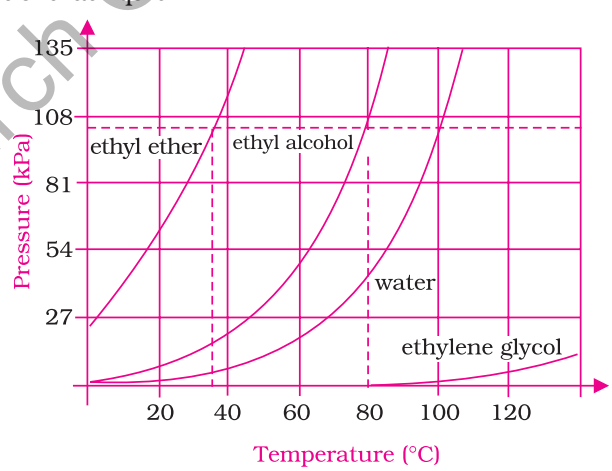
Substance	Tc (K)	Pc(bar)	Vc(dm3mol-1)
Hydrogen	33.2	12.97	0.0650
Helium	5.3	2.29	0.0577
Nitrogen	126.0	33.9	0.0900
Oxygen	154.3	50.4	0.0744
Carbon dioxide	304.15	73.9	0.0956
Ammonia	405.5	113.0	0.0723
Water	647.1	220.6	0.0450

- **Evaporation v/s Boiling :** Evaporation is a surface phenomenon, that occurs at a large range of temperature while boiling is a bulk phenomenon that takes place at a specific temperature when vapour pressure becomes equal to atmospheric pressure.
- A given liquid such as water can be made to boil at the temperature below its standard boiling temperature of 100°C at sea level by lowering the pressure in its surroundings or it can be raised by increasing the pressure such as in a pressure cooker.
- **Enthalpy of vapourisation or evaporation :** It refers to the amount of heat required to evaporate a mole of a liquid at a given temperature such as water : it is 44,180KJ at 25°C.

$$H_2O_{(l)} + 44,180KJ \rightarrow H_2O_{(g)}$$

- **Vapour pressure curve :** A vapour pressure curve is a graph of vapour pressure as a function of temperature. To find the normal boiling point of a liquid, a horizontal line is drawn from the left at a pressure equal to standard pressure. At whatever temperature that line intersects the vapour pressure curve of a liquid is the boiling point of that liquid.



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Chapter 6

THERMODYNAMICS

Chemical thermodynamics, thermodynamics and types of equilibrium, laws of thermodynamics, heat, temperature, heat transfer: conduction, convection and radiation,Intenal energy, enthalpy, types of enthalpy, Gibbs free energy, entropy, types of thermodynamic processes, Carnot cycle, Phase change, Bomb calorimeter.

- **Thermodynamics :** It is a branch of science that deals with the study of heat and temperature and their relation to energy and work.
- **Chemical energy :** It is the potential of a chemical substance to undergo a transformation through a chemical reaction or to transform other chemical substances. Breaking or making of chemical bonds involves energy or heat, which may be either absorbed or evolved from a chemical system.
- **Chemical thermodynamics :** It is the study of the inter-relation of energy with chemical reactions or with a physical change of state within the confines of the laws of thermodynamics.
- **Thermodynamics and equilibrium :** Thermodynamics can be equilibrium or non-equilibrium thermodynamics depending upon the system and the surroundings.
- **Equilibrium thermodynamics :** It refers to the systematic study of the transformation of matter and energy in systems as they approach equilibrium. The word equilibrium implies a state of balance. In an equilibrium state, there are no unbalanced potentials, or driving forces, within the system. A central aim in equilibrium thermodynamics that is : given a system in a well-defined initial state, subject to accurately specified constraints, to calculate what the state of the system will be once it has reached equilibrium.

  In an isolated system, it occurs when there is no change in the macroscopic property of the system like entropy, internal energy etc.
- **Non-equilibrium thermodynamics :** It is a branch of thermodynamics that deals with systems that are not in thermodynamic equilibrium. Most systems found in nature are not in thermodynamic equilibrium because they are not in stationary states, and are continuously and discontinuously subject to the change of matter and energy to and from other systems.
- **Laws of thermodynamics :** Thermodynamics is principally based on a set of four laws. These are :
- **Zeroth law of thermodynamics :** It states, "*If each of the two systems is in thermal equilibrium with a third, they are also in thermal equilibrium with each other.*"

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- It implies that thermal equilibrium is an equivalence relation on the set of thermodynamic systems under consideration. Systems are said to be in equilibrium if the small, random exchanges between them (e.g. Brownian motion) do not lead to a net change in energy. This law is tactily assumed in every measurement of temperature. The law provides an empirical definition of temperature and justification for the construction of practical thermometers.
- **First law of thermodynamics:** It states that t*he internal energy of an isolated system is constant, i.e.*
- It is more an expression of the principle of conservation of energy. It states that energy can be transformed (changed from one form to another), but cannot be created or destroyed.
- This law is usually formulated by saying that the change in the internal energy of a closed thermodynamic system is equal to the difference between the heat supplied to the system and the amount of work done by the system on its surroundings.
- **Second law of thermodynamics**: It states that *heat cannot spontaneously flow from a colder location to a hotter location.* This law of thermodynamics is an expression of the universal principle of decay observable in nature that over the time, differences in temperature, pressure, and chemical potential tend to even out in a physical system that is isolated from the outside world. Entropy is a measure of how much this process has progressed. The entropy of an isolated system which is not in equilibrium will tend to increase over the time, approaching a maximum value at equilibrium.
- In classical thermodynamics, the law is a basic postulate applicable to any system involving heat energy transfer and a consequence of the assumed randomness of molecular chaos.
- **Third law of thermodynamics**: It states that *as a system approaches absolute zero, all processes cease and the entropy of the system approaches a minimum value* .It is more a law of nature regarding entropy and the impossibility of reaching the absolute zero of temperature. This law provides an absolute reference point for the determination of entropy that "the entropy of all systems and of all states of a system is the smallest at absolute zero," or equivalently "it is impossible to reach the absolute zero of temperature by any finite number of processes".
- Absolute zero is the temperature at which all activity would stop if it were possible to happen it is –273.15 °C (degrees Celsius), or –459.67 °F (degrees Fahrenheit) or 0 K (kelvin).
- **Heat :** It is a form of energy; it always remains conserved, *i.e.* it cannot be created or destroyed. It can, however, be transferred from one place to another. Heat can also be converted to and from other forms of energy. For example, a steam turbine can convert heat to kinetic energy to run a generator that converts kinetic energy to electrical energy. A light bulb can convert this electrical energy

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to electromagnetic radiation (light), which, when absorbed by a surface, is converted back into heat.

- **Temperature :** It is "a measure of the average kinetic energy of the particles in a sample of matter, expressed in terms of units or degrees designated on a standard scale". The most commonly used temperature scale is Celsius, which is based on the freezing and boiling points of water, assigning respective values of 0°C and 100°C. The Fahrenheit scale is also based on the freezing and boiling points of water which have assigned values of 32°F and 212°F, respectively.
- Scientists worldwide, however, use the Kelvin (K with no degree sign) scale, named after William Thomson, 1st Baron Kelvin, because it works in calculations. Kelvin scale is a scale of temperature with absolute zero as zero, and the triple point of water are exactly 273.16 degrees. This scale uses the same increment as the Celsius scale, i.e. a temperature change of 1°C is equal to 1 K. However, the Kelvin scale starts at absolute zero. The temperature at which there is a total absence of heat energy and all molecular motion stops. A temperature of 0 K is equal to minus 459.67°F or minus 273.15°C.
- **Specific heat :** The amount of heat required to increase the temperature of a certain mass of a substance by a certain amount is called specific heat, or specific heat capacity. Its conventional unit is calories per gram per Kelvin(cal $g^{-1}K^{-1}$) or (kcal $kg^{-1}K^{-1}$) . A calorie is defined as the amount of heat energy required to raise the temperature of 1 gram of water at 4°C by 1°C.

Calorific values of some common fuels and foods

Fuel	Calorific value(KJ/g)	Fuel	Calorific value(KJ/g)
Charcoal	33	Butter	30.4
Wood	17	Ghee	37.6
Cowdung cake	6-8	Milk	3.2
Kerosene	48	Curd	2.5
Fuel oil	45	Honey	13.3
Hydrogen	150	Rice	14.5
Methane	55	Egg	7.3

- **Heat transfer :** Heat can be transferred from one body to another or between a body and the environment by three different means: conduction, convection and radiation.
- **Conduction :** It is the transfer of energy *through* solid material. Conduction between bodies occurs when they are in direct contact, and molecules transfer their energy across the interface.

  Ex: Ice cooling down your hand, Boiling water by thrusting a red-hot piece of iron into it.

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- **Convection :** It is the transfer of heat to or from a fluid medium. Molecules in a gas or liquid in contact with a solid body transmit or absorb heat to or from that body and then move away, allowing other molecules to move into place and repeat the process. Efficiency can be improved by increasing the surface area to be heated or cooled, as with a radiator, and by forcing the fluid to move over the surface, as with a fan.

  Ex : Hot air rising, cooling and falling, An old fashioned radiator.
- **Radiation :** It involves the emission of electromagnetic (EM) energy, particularly infrared photons that carry heat energy. All matter emits and absorbs some EM radiation, the net amount of which determines whether this causes a loss or gain in heat.

  Ex: Heat from fire, heat from a light bulb.
- **Internal energy :** It is the change in energy that occurs during the course of a chemical reaction, where $\Delta U^0_{Reactant}$ is the internal energy of formation of the reactant molecules that can be calculated from the bond energies of the various chemical bonds of the molecules under consideration and $\Delta U^0_{Reactant}$ is the internal energy of formation of the product molecules. The change in internal energy is a process which is equal to the heat change if it is measured at STP condition as in a closed rigid container such as a bomb calorimeter.
- However, under the conditions of constant pressure, as in reactions in vessels open to the atmosphere, the measured heat change is not always equal to the internal energy change, because pressure-volume work also releases or absorbs energy.
- The internal energy and temperature of a system decrease ($\Delta E < 0$) when the system either loses heat or does work on its surroundings. Conversely, the internal energy and temperature increase ($\Delta E > 0$) when the system gains heat from its surroundings or when the surroundings do work on the system. Enthalpy, for of a homogeneous system, is defined as : $H = U + pV$
- where H is the enthalpy, U is the internal energy, p is the pressure and V is the volume of the system.
- The enthalpy is an extensive property, *i.e.* for homogeneous systems, it is proportional to the size of the system.
- For a homogeneous system, it can be viewed as function H of the entropy S and the pressure p, and a differential relation for it can be derived as follows:
- In a closed systems for an infinitesimal process:

$$dU = \delta\theta - \delta W$$

- Here, ∂Q is a small amount of heat added to the system, and δW a small amount of work performed by the system and $\partial\theta = T\,\partial S$, with T the absolute temperature of the system. When $\partial W = p.dV$

  Adding $d(pV)$ to both sides of this expression gives

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$\partial u = T\partial S - p\partial V$

adding $\partial(pV)$ to both sides,

$\partial u + \partial(pV) = T\partial S - p\partial V + \partial(pV)$

$\partial (u + pV) = T\partial S + V\partial p$

$\partial H = T\partial S + V\partial p$

- **Enthalpy of reaction :** The enthalpy change observed in a constituent of a thermodynamic system when one mole of substance reacts completely.

  Enthalpy of reaction is the amount of energy or heat absorbed in a reaction. If the energy is required, ΔH is positive, and if energy is released, ΔH is negative.

  For an exothermic reaction ΔH or Δu is negative and for exothermic reaction ΔH is positive.
- **Enthalpy of formation :** The enthalpy change observed in a constituent of a thermodynamic system when one mole of a compound is formed from its elementary antecedents.
- **Enthalpy of combustion :** The enthalpy change observed in a constituent of a thermodynamic system when one mole of a substance burns completely with oxygen.
- **Enthalpy of hydrogenation :** The enthalpy change observed in a constituent of a thermodynamic system when one mole of an unsaturated compound reacts completely with an excess of hydrogen to form a saturated compound.
- **Enthalpy of neutralization :** The enthalpy change observed in a constituent of a thermodynamic system when one mole of water is formed, *e.g.* when an acid and a base react or vice versa.
- **Enthalpy of solution :** The enthalpy change observed in a constituent of a thermodynamic system when one mole of a solute is dissolved completely in an excess of solvent, so that the solution is at infinite dilution.
- **Enthalpy of hydration :** The enthalpy change observed when one mole of gaseous ions is completely dissolved in water forming one mole of aqueous ions.
- **Enthalpy of fusion :** The enthalpy change required to completely change the state of one mole of substance between solid and liquid states.
- **Enthalpy of vaporization :** The enthalpy change required to completely change the state of one mole of substance between liquid and gaseous states.
- **Enthalpy of sublimation :** The enthalpy change required to completely change the state of one mole of substance between solid and gaseous states.
- **Lattice enthalpy**: It is defined as the energy required to separate one mole of an ionic compound into separated gaseous ions to an infinite distance apart (meaning no force of mutual attraction).

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- **Stagnation enthalpy :** (h_t) is the enthalpy of a flow at a stagnation point. It is the enthalpy at a stagnation point (zero velocity) if the flow is brought to a stop from velocity v.
- Total enthalpy is the same at every point in a flow field, so the stagnation enthalpy at a stagnation point is identical to the total enthalpy everywhere in the flow field.

$$h_t = h + v^2/2$$

- where h is enthalpy, and v is velocity.
- Stagnation enthalpy has units of energy. If enthalpy is thought of as the energy associated with the temperature plus the energy associated with the pressure, the stagnation enthalpy adds a term associated with the kinetic energy of the fluid mass.
- **Isenthalpic process :** It also called as Isoenthalpic process, is a process that proceeds without any change in enthalpy, H or specific enthalpy, h. In a steady-state, in a steady-flow process, significant changes in pressure and temperature can occur to the fluid and yet the process will be isenthalpic if there is no transfer of heat to or from the surroundings, no work done on or by the surroundings, and no change in the kinetic energy of the fluid.
- The throttling process is a good example of an isenthalpic process such as the lifting of a relief valve or safety valve in a pressure vessel. The specific enthalpy of the fluid inside the pressure vessel is the same as the specific enthalpy of the fluid as it escapes from the valve.
- In an isenthalpic process: $h_1 = h_2 \Rightarrow dh = 0$
- Isenthalpic processes on an ideal gas follow isotherms since

$$\partial h = 0 = c_p \partial T$$

- **Gibbs free energy:** For any system at any moment in time Gibbs energy is defined as the enthalpy of the system minus the product of the temperature times the entropy of the system.

$$G = H - TS$$

- The Gibbs free energy of the system is a state function because it is defined in terms of thermodynamic properties that are state functions. The change in the Gibbs free energy of the system that occurs during a reaction is equal to the change in the enthalpy of the system minus the change in the product of the temperature times the entropy of the system.

$$\Delta G = \Delta H - \Delta(TS)$$

- If the reaction is run at constant temperature, this equation can be written as follows:

$$\Delta G = \Delta H - T\Delta S$$

- In the standard-state free energy of reaction

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

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- The change in the free energy of the system that occurs during a reaction measures the balance between the two driving forces that determine whether a reaction is spontaneous or not.

  Favorable *Unfavorable*

  $H° < 0$ $H° > 0$

- For any reaction in which $\Delta H°$ is negative, $\Delta S°$ is positive and $\Delta G°$ is negative should be favorable, or spontaneous.

  Favorable, or spontaneous reactions : $\Delta G° < 0$

- Conversely, $G°$ is positive for any reaction in which $H°$ is positive and $S°$ is negative. Any reaction for which $\Delta G°$ is positive is, therefore, unfavorable.

  Unfavorable, or non-spontaneous reactions : $\Delta G° > 0$

- ΔG is negative for a spontaneous process while positive for a non-spontaneous process but when equal to zero , the process is in equilibrium state.
- Reactions are classified as either exothermic ($\Delta H < 0$) or endothermic ($\Delta H > 0$) on the basis of whether they give off or absorb heat. Reactions can also be classified as exergonic ($\Delta G < 0$) or endergonic ($\Delta G > 0$) on the basis of whether the free energy of the system decreases or increases during the reaction.
- **Hess's law :** It states that the change of enthalpy in a chemical reaction (*i.e.* the heat of reaction at constant pressure) is independent of the pathway between the initial and final states, *i.e.* if a chemical change takes place by several different routes, the overall enthalpy change is the same, regardless of the route by which the chemical change occurs , provided the initial and final condition are the same.
- Hess's law allows the enthalpy change (ΔH) for a reaction to be calculated even when it cannot be measured directly.
- Hess's law states that enthalpy changes are additive. Thus, the ΔH for a single reaction

$$\Delta H = \Sigma\Delta H_{f(Product)} - \Sigma\Delta H_{f(Reactant)}$$

- where H_f is an enthalpy of formation, and the superscript indicates standard state values. This may be considered as the sum of two (real or fictitious) reactions:

  Reactants/(Elements) (Elements)/ Products

  $\Delta H_f = -\Sigma\Delta H_{f(Reactant)}$ $\Delta H_f = \Sigma\Delta H_{f(Product)}$

Problem : Given

B_2O_3 (s) + $3H_2O$ (g) $\rightarrow$ $3O_2$ (g) + B_2H_6 (g) (ΔH = 2035 kJ/mol)

H_2O (l) $\rightarrow$ H_2O (g) (ΔH = 44 kJ/mol)

H_2 (g) + (1/2)O_2 (g) $\rightarrow$ H_2O (l) (ΔH = -286 kJ/mol)

2B (s) + $3H_2$ (g) $\rightarrow$ B_2H_6 (g) (ΔH = 36 kJ/mol)

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Find the ΔHf of : $2B (s) + (3/2) O_2 (g) \rightarrow B_2O_3 (s)$

Solution : After the multiplication and reversing of the equations (and their enthalpy changes), the result is:

$B_2H_6 (g) + 3O_2 (g) \rightarrow B_2O_3 (s) + 3H_2O (g)$ (ΔH = -2035 kJ/mol)

$3H_2O (g) \rightarrow 3H_2O (l)$ (ΔH = -132 kJ/mol)

$3H_2O (l) \rightarrow 3H_2 (g) + (3/2) O_2 (g)$ (ΔH = 858 kJ/mol)

$2B (s) + 3H_2 (g) \rightarrow B_2H_6 (g)$ (ΔH = 36 kJ/mol)

- Adding these equations and cancelling out the common terms on both sides, we get

  $2B (s) + (3/2) O_2 (g) \rightarrow B_2O_3 (s)$ (ΔH = -1273 kJ/mol)

- **Entropy :** It is the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work as proposed by Rudolf Clausius in 1850 because work is obtained from ordered molecular motion, the amount of entropy is also a measure of the molecular disorder, or randomness of a system. The concept of entropy provides deep insight into the direction of spontaneous change for many everyday phenomena as an expression of the disorder, or randomness of a system. Hence, being an extensive property, it has the dimension of energy divided by temperature, which has a unit of joules per kelvin ($J K^{-1}$), in S.I. units ($kg\ m^2\ s^{-2}\ K^{-1}$ in terms of base units). But the entropy of a pure substance is usually given as an intensive property either entropy per unit mass (SI unit: $J\ K^{-1}\ kg^{-1}$) or entropy per unit amount of substance (SI unit: $J\ K^{-1}\ mol^{-1}$).
- If an amount of heat Q flows into a large heat reservoir at temperature T above absolute zero, then the entropy increase is $\Delta S = Q/T$.
- Assume that there are two heat reservoirs R_1 and R_2 at temperatures T_1 and T_2 (such as the stove and the block of ice). If an amount of heat Q flows from R_1 to R_2, then the net entropy change for the two reservoirs is

$$\Delta S = Q\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

- It is positive provided that $T_1 > T_2$. Thus, the observation that heat never flows spontaneously from cold to hot is equivalent to requiring the net entropy change to be positive for a spontaneous flow of heat. If $T_1 = T_2$, then the reservoirs are at equilibrium; no heat flows, and $\Delta S = 0$.
- The condition ΔS=0 determines the maximum possible efficiency of heat engines that is, systems such as gasoline or steam engines that can do work in a cyclic fashion. Suppose a heat engine absorbs heat Q_1 from R_1 and exhausts heat Q_2 to R_2 for each complete cycle.

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By conservation of energy, the work done per cycle is $W = Q_1 - Q_2$, and the net entropy change is

$$\Delta S = \frac{Q_2}{Q_1} - \frac{T_2}{T_1}$$

- To make W as large as possible, Q_2 should be as small as possible relative to Q_1. However, Q_2 cannot be zero, because this would make ΔS negative and so violate the second law. The smallest possible value of Q_2 corresponds to the condition $\Delta S = 0$, yielding

$$\left(\frac{Q_2}{Q_1}\right)_{min} = \frac{T_2}{T_1}$$

- As the fundamental equation limiting the efficiency of all heat engines. A process for which $\Delta S = 0$ is reversible because an infinitesimal change would be sufficient to make the heat engine run backward as in a refrigerator.

Types of thermodynamic processes	
Adiabatic	➢ It's a process in which no heat or mass is transferred between the system and its surroundings ($\Delta m=0$, $\Delta Q=0$). In practice, this assumption is most often used for rapidly acting systems (*i.e.* the thermodynamic process occurs in a short period) or as a method for obtaining conservative results. For example: ➢ Analysing the stroke of a piston where heat transfer outside of the system can be minimal due to the short period of time analysed. ➢ The analysis of a combustion reaction using the adiabatic assumption to give an upper limit (conservative) estimate of the flame temperature (referred to as the adiabatic flame temperature).
Isenthalpic	➢ It's a process in which there is no transfer of heat energy to or from the surroundings as if the system were surrounded by a perfect insulator ($\Delta h=0$). ➢ Essentially, an isenthalpic system is an adiabatic system that is irreversible and extracts no work. ➢ The isenthalpic assumption is typically applied to determine the maximum temperature change in a system with changes in pressure. For example in calculating the temperature of a gas after it has passed through a safety relief valve to ensure that downstream components are suitably rated for the discharge temperature.

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Isentropic	➢ It's a process in which entropy remains constant ($\Delta S=0$). ➢ Since no energy is dissipated as heat, an isentropic process is both adiabatic and reversible. ➢ Steady state fluid systems are often best represented as adiabatic but to give an estimation of the efficiency of the process, the isentropic performance of a system is often related to the adiabatic or actual performance. This is referred to as the adiabatic or isentropic efficiency. ➢ For systems where pressure decreases, such as turbines and nozzles: $S^{\eta}=\frac{h_1-h_{2a}}{h_1-h_{2s}}$ ➢ For systems where pressure increases, such as pumps and compressors: $\eta=\frac{h_{2s}-h_1}{h_{2a}-h_1}$
Isobaric	➢ It's a process in which the pressure is held constant ($\Delta P=0$) ➢ Assuming that the quantity of gas in an isobaric process remains constant, the work done by the system is directly proportional to the change in volume or temperature of the system. ➢ The ratio of heat capacity of a gas in an isobaric system with the heat capacity of the gas in an isochoric system makes up the ratio of specific heats for gases K = Cp/Cv
Isochoric	➢ An isochoric system is the one in which volume is held constant ($\Delta V=0$). Isochoric processes can also be referred to as isometric or isovolumetric. For example, in calorimetry, the energy of a reaction may be measured in a **"Bomb calorimeter"**. This device does not change volume during the reaction so that the temperature change may be measured as a single variable, and used to calculate the energy released.
Isothermal	➢ It's process in which there is no temperature change ($\Delta T=0$). There may be energy flow into and out of the system. However, only the amount required to keep the temperature of the system is constant. For example: ➢ Phase changes - melting solids and boiling liquids of pure substances require substantial energy transfer, but does not change temperature. (Latent heat)

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Isotropic	➢ An isotropic system is not strictly a thermo-dynamics system. These systems are uniform regardless of direction. For example: ➢ Radiation may be isotropic when the observed intensity is the same in all directions from the source. ➢ A fluid may be called isotropic if the relationships between stress and rate of strain is the same in all directions.
Polytropic	➢ A Polytropic fluid system follows the relationship: $PV^n = C$. From this relationship it's clear that when – n=0, the process is isobaric – n= 1, the process is isothermal – n=k, the process is isentropic – n= ∝ the process is isochoric
Reversible	➢ A reversible process is the one which is performed as if it were always at equilibrium, and without the production of entropy. This system is purely hypothetical since entropy is increased by any process occurring in a finite time. However, it is always at equilibrium as the process progresses and thus represents the maximum efficiency that is possible in the conversion between work and energy for the system.

Constant properties for each type of thermodynamic process

Process	Properties Held Constant	Process	Properties Held Constant
Adiabatic	Heat Energy	Isobaric	Pressure
Isenthalpic	Enthalpy	Isochoric	Volume
Isentropic	Entropy, Equilibrium, Heat Energy	Isothermal	Temperature
Isotropic	Direction	Polytropic	$PV^n = C$

➢ **Carnot's Theorem :** During one part of the cycle performed in an engine, some heat is absorbed from a hot reservoir. During another part, a smaller amount of heat is rejected to a cooler reservoir. The engine is therefore said to operate between these two reservoirs. However, some heat is always rejected to the cooler reservoir. Because of this, the efficiency of an actual engine is never 100%. For an ideal gas Carnot cycle, the four steps are shown below:

➢ **Isothermal expansion** from V_a, P_a to V_b, P_b at T_{hot} absorbing heat Q_h. In this the temperature is constant.

➢ **Reversible adiabatic expansion** from V_b, P_b to V_c, P_c as the temperature falls from T_{hot} to T_{cold}.

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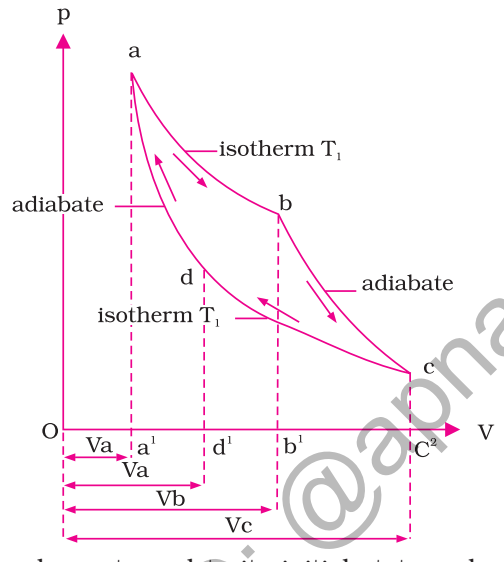
- Isothermal contraction from V_c, P_c to V_d, P_d at T_{cold} exhausting heat Q_c.
- Reversible adiabatic contraction from V_d, P_d to V_a, P_a as the temperature rises from T_{cold} to T_{hot}.



The system has returned to its initial state and an amount of work, W, has been done to the system. By the conservation of energy, $W = Q_h - Q_c$

The thermal efficiency, η, of a cycle operating as heat engine is defined as $\eta = W/|Q_h|$

- The efficiency of the cycle in terms of the Q_c and Q_h,

$$\eta = 1 - |Q_c|$$

- **Quasistatic process :** It is an idealized or fictive model of a thermodynamic "process" considered in theoretical studies. It does not occur in physical reality. It may be imagined as happening infinitely slowly so that the system may pass through a continuum of states that are infinitesimally close to equilibrium.
- **Phase change :** It involves the transitions between the solid, liquid and gaseous phases of a single component, due to the effects of temperature and/or pressure :

Metal→ ↓	Solid	Liquid	Gas	Plasma
Solid	Solid-solid Transformation	Melting	Sublimation	—
Liquid	Freezing	—	Boiling/ Evaporation	—
Gas	Deposition	Condensation	—	Ionization
Plasma	—	—	Recombination Deionization	—

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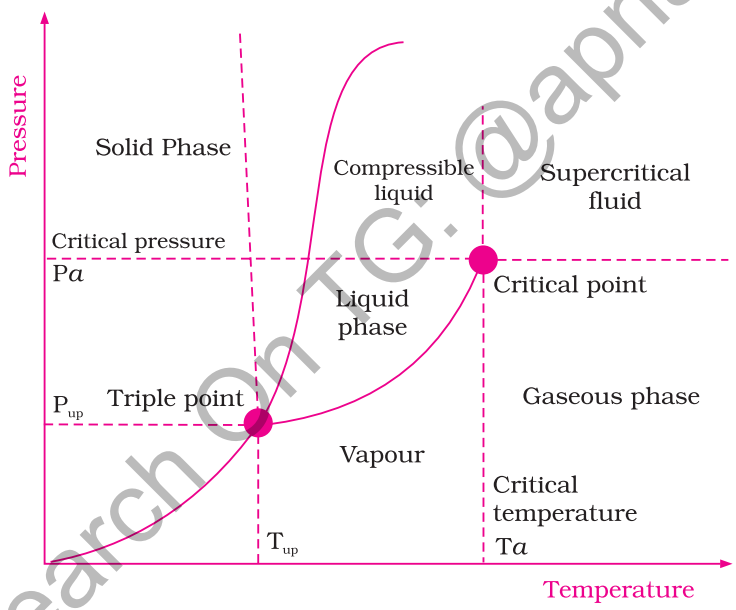
- **Isotope fractionation :** It is the process that affect the relative abundance of isotopes. When water vapour condenses (an equilibrium fractionation), the heavier water isotopes (18-O and 2-H) become enriched in the liquid phase while the lighter isotopes (16-O and 1-H) tend towards the vapour phase.
- **Quantum condensation :** It refers to Bose–Einstein condensation of bosonic fluids. The super fluid transition in liquid helium is an example of this.
- **Spinodal decomposition :** It involves the phase change in which a single phase is cooled and separates into two different compositions of the same phase.
- **Eutectic transformation :** It's the transformation, in which a two-component single-phase liquid is cooled and transforms into two solid phases. The same process, but beginning with a solid instead of a liquid, is called aeutectoid transformation.



A typical phase diagram.

The dotted line gives the anomalous behaviour of water

- **Peritectic transformation :** It's the transformation in which a two-component single phase solid is heated and transforms into a solid phase and a liquid phase.
- **Mesophase:** It occurs between solid and liquid, such as one of the "liquid crystal" phases.
- **Purpose of Bomb Calorimetry Experiments:** Bomb calorimetry is used for determining the enthalpy of combustion, $D_{comb}H$, for hydrocarbons:

$$C_xH_YO_{z\,(s)} + (2X+Y/2-Z)/2\ O_{2\,(g)} \rightarrow X\ CO_{2\,(g)} + Y\ H_2O_{(l)}$$

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Since combustion reactions are usually exothermic (give off heat), $D_{comb}H$ is typically negative.

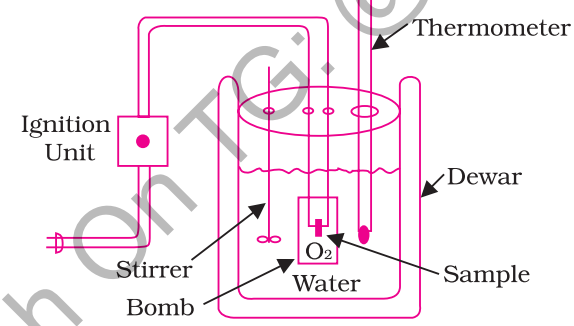
- **Construction of a Bomb Calorimeter:** The bomb calorimeter consists primarily of the sample, oxygen, the stainless steel bomb (vessel) and water. The dewar prevents heat flow from the calorimeter to the rest of the universe, *i.e.* $q_{calorimeter} = 0$
- Since the bomb is made from stainless steel, the combustion reaction occurs at constant volume and there is no work, *i.e.*

$$w_{calorimeter} = -0.pdV = 0$$

- Thus, the change in internal energy, D*U*, for the calorimeter is zero

$$DU_{calorimeter} = q_{calorimeter} + w_{calorimeter} = 0$$

- The thermodynamic interpretation of this equation is that the calorimeter is isolated from the rest of the universe.
- **Bomb Calorimeter and Internal energy change (DU):** Since the calorimeter is isolated from the rest of the universe, we can define the reactants (sample and oxygen) to be the system and the rest of the calorimeter (bomb and water) to be the surroundings. The change in internal energy of the reactants upon combustion can be calculated from



$$dU_{tot} = dU_{sys} + dU_{surr} = 0$$
$$dU_{sys} = -dU_{surr}$$

$$= -\left[\left(\frac{\partial U}{\partial T}\right)_v dT + \left(\frac{\partial U}{\partial V}\right)_r dV\right]$$

- In the process, the constant volume, dV=0. Thus, recognizing the definition of heat capacity C_v yields

$$dU_{sys} = -C_v dT$$

- Assuming C_v to be independent of T over small temperature ranges, this expression can be integrated to give

$$\Delta U = -C_v \Delta T$$

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- where C_v is the heat capacity of the surroundings, *i.e.* the water and the bomb.
- **Bomb Calorimeter and Enthalpy change (DH) :** Enthalphy change

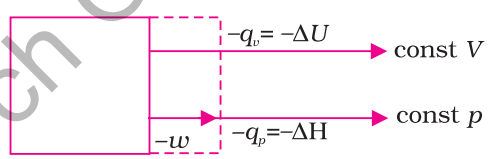
$$\Delta H = \Delta U + \Delta(pV)$$

Since there is very little expansion work done by condensed phases, d(Pv) >> 0 for solids and liquids. Assuming the gas to be ideal yields

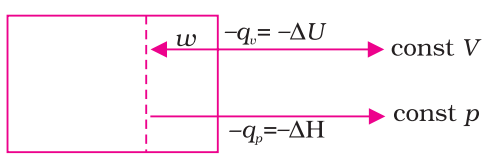
$$\Delta H = \Delta U + RT\Delta n_{gas}$$

- **Intuitive difference between DU and DH :** The difference between these two situations is that pV work can be done under constant pressure conditions, whereas no pV work is done under constant volume.
- Consider the case where $Dn_{gas} > 0$, *i.e.* the system expands during the reaction. The same amount of energy is released by the reaction under both sets of conditions. However, some of the energy is released in the form of work at constant pressure; thus, the heat released will be less than at constant volume. Mathematically, Heat released < energy released , $-DH < -DV$ or $-DH > -DV$
- In case where $Dn_{gas} < 0$. *i.e.* the system contracts during the reaction, the surroundings does work on the system. Thus, this work is available for energy release from the system back to the surroundings in the form of heat. Mathematically, heat released is greater than energy released
- Therefore, $-DH > -DU$ *Or* $DH < DU$
- These cases can be depicted pictorially as follows:

$Dn_{gas} > 0$ work done by system-$DH < -DU$ or $DH > DU$



$Dn_{gas} < 0$ work done on system-$DH > -DU$ or $DH < DU$



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Chapter 7

EQUILIBRIUM

CHEMISTRY

Physical equilibrium, chemical equilibrium, state of equilibrium in reversible reactions, law of mass action, law of chemical equilibrium, equilibrium constant and its units, relation between K_p and, K_c, characteristics of equilibrium constant, applications of equilibrium constant, relation between equilibrium constant K, reaction quotient Q and Gibbs free energy, D G, Le-Chatelier's principle and its applications, factors affecting equilibrium constant, ionic equilibrium,Ostwald's dilution law, calculation of pH and pOH of electrolytes, relation between K_a and K_b, polyprotic acids and bases, buffer solutions, Henderson - Hausselbatch equation and solubility product.

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- **Equilibrium :** It refers to a state of balance between opposing forces or actions that is either static (as in a body acted on by forces whose resultant is zero) or dynamic (as in a reversible chemical reaction when the rates of reaction in both directions are equal).
- **Physical equilibrium :** It is defined as the equilibrium which develops between different phases or physical properties. In these processes, there is no change in chemical composition. The following are some examples of physical equilibria.
- **Solid-Liquid Equilibria :** The state when solid and liquid phases of a substance are involved is called solid liquid equilibrium. Consider ice and water in a perfectly insulated thermos flask at 0°C in an open atmosphere. There will be no change in the level of water and quantity of ice, which implies that the rate of transfer of molecules from water to ice is equal to the rate of transfer of molecules from ice to water. Hence, we can conclude that this system is in steady state. It can be represented as :

  Rate of melting = Rate of freezing ($H_2O_{(s)} \rightleftharpoons H_2O_{(l)}$)
- **Saturated and unsaturated solution :** A saturated solution is the solution formed when no more solute can be dissolved in a given solvent at a specific temperature as compared to a solution in which a solute can further be dissolved in the solvent. The point of temperature at which a formed solution becomes completely saturated is called saturation point.
- **Liquid-Gas Equilibria :** Take distilled water in a closed container and start heating; the water converts to vapour. After a certain time, we will observe that the level of water becomes constant implying that there is no more conversion of water to vapour and vice versa, *i.e.* the rate of evaporation (liquid to vapour) is equal to the rate of condensation (vapour to liquid) thus achieving steady state. It can be represented by as:

  Rate of evaporation = Rate of condensation ($H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$)
- **Henry's law :** The law describes the dependence of the solubility of a gas in a liquid at a given pressure. It states that the mass of a gas

dissolved in a given mass of a solvent at a particular temperature is proportional to the pressure of the gas above the solvent.

Ex: One's experience with carborated soft drinks which contain dissolved CO_2. The dissolved CO_2 fizzes when the bottle is opened.

- **Solid-Vapour Equilibria :** This kind of equilibrium exists only in case of sublimates (solid directly converts to vapour). Consider the heating of solid iodine in a closed container; slowly the vessel is filled with violet coloured vapour and the intensity of colour increases with time. After a certain time, the intensity of colour doesn't change with time. It shows that steady state has been attained when the rate of sublimation of solid iodine is equal to the rate of deposition of iodine vapour.

  Rate of sublimation = Rate of deposition $(I_{2\,(s)} \rightleftharpoons I_{2\,(vap)})$

Constant values at equilibrium	
Process	**Expression that require equilibrium constant value**
Liquid $\rightleftharpoons$ Vapour	Pressure at constant temperature
Solid $\rightleftharpoons$ Liquid	Melting point at constant pressure
$Solute_{(s)} \rightleftharpoons Solute_{(aq)}$	Concentration of solute in solution
$Gas_{(g)} \rightleftharpoons Gas_{(aq)}$	$Gas_{(aq)}/Gas_{(g)}$ at given temperature

Physical equilibrium v/s chemical equilibrium:

- Physical equilibrium does not involve changes to the chemical properties of the substances involved. For instance, the equilibrium of water vapour with liquid water in a partly filled sealed bottle. It is a physical equilibrium since the water molecules have only changed form liquid to vapour.
- Chemical equilibrium involves changes in the chemical composition of substances. Bond breaking and bond formation is involved such as the dissociation of acetic acid . There is an interchange of particles between ions and molecules whose rate of exchange becomes equal when equilibrium is established.

$$CH_3COOH + H_2O \longrightarrow H_3O^+ + CH_3COO^-$$

- **Reversible reaction :** It is a reaction where the reactants form products, which react together to give the reactants back.

$$aA + bB \rightleftharpoons cC + dD$$

- A and B can react to form C and D or, in the reverse reaction, C and D can react to form A and B. This is distinct from reversible process in thermodynamics.
- Weak acids and bases undergo reversible reactions. For example, carbonic acid:

$$H_2CO_{3\,(l)} + H_2O_{(l)} \rightleftharpoons HCO^-_{3\,(aq)} + H_3O^+_{(aq)}$$

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- The concentrations of reactants and products in an equilibrium mixture are determined by the analytical concentrations of the reagents (A and B or C and D) and the equilibrium constant, K. The magnitude of the equilibrium constant depends on the Gibbs free energy change for the reaction. When the free energy change is large (more than 30 kJ mol"1), then the equilibrium constant is large (log K > 3) and the concentrations of the reactants are very small. Such a reaction is sometimes considered to be an irreversible reaction. Although in reality small amounts of the reactants are still expected to be present in the reacting system. A truly irreversible chemical reaction is usually achieved when one of the products exits the reacting system, for example, as does carbon dioxide (volatile) in the reaction

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2\uparrow$$

- **Irreversible reactions:** These are unidirectional reactions in which the reactants once convert to products; the products *cannot* convert back to the reactants. These reactions are essentially like baking. An example of an irreversible reaction is combustion. It involves burning an organic compound such as a hydrocarbon and oxygen to produce carbon dioxide and water. Because water and carbon dioxide are stable, they do not react with each other to reform the reactants. The reactions take the following form:

$$C_xH_y + O_2' \rightarrow CO_2 + H_2O + \text{Heat}$$

- **Reaction Quotient (Q) :** It's a mathematical expression relating the concentrations of reactants and products at any stage of a reaction:

Consider a general chemical reaction reaction $aA + bB \rightleftharpoons cC + dD$

$$\text{then } Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

- The expression for Q may be written down by the inspection of the balanced chemical equation. It is the product of the instantaneous concentrations of the reaction products each raised to the power of its stoichiometric coefficient divided by the product of the instantaneous concentrations of the reactants, each raised to the power of its stoichiometric coefficient. Here, the square bracket notation, e.g. [A], is used as the symbol for concentration rather than c(A). The form c(A), usually represents the overall concentration of a species disregarding any reactions which might have occurred.
- On heating the blue solid, hydrated copper(II) sulphate, steam is given off and the white solid of anhydrous copper(II) sulphate is formed.When the white solid is cooled and water added, blue hydrated copper(II) sulphate is reformed, *i.e.* a reversible reaction.

Examples of reversible reactions :

Thermal decomposition of hydrated copper sulphate :

Blue hydrated copper(II) sulphate + heat gives White anhydrous copper(II) sulphate + water

$$CuSO_4.5H_2O_{(s)} \rightleftharpoons CuSO_{4(s)} + 5H_2O_{(g)}$$

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- The dehydration on heating to give the white solid is the forward endothermic reaction and the 're-hydration' to reform the blue crystals is the backward exothermic reaction.
- This test is commonly used to test the presence of water or moisture. Anhydrous copper sulphate exposed to moisture turns blue.
- The synthesis of ammonia from nitrogen and hydrogen is a reversible reaction and by changing the temperature and pressure of the reacting gases one can make the reaction go one way or another, e.g., high pressure makes more ammonia (forward reaction) and higher temperature causes ammonia to decompose into hydrogen and nitrogen (backward reaction).

$$\text{Nitrogen} + \text{Hydrogen} \rightleftharpoons \text{Ammonia}$$

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

- The forward reaction forms the basis of ammonia manufactured by Haber's Process used in nitrogen fertilizers producing industries.
- If the pressure is reduced, or the temperature raised, the reaction tends to reverse to give a greater proportion of nitrogen and hydrogen. If the pressure is increased, or the temperature lowered, the reaction tends to give a greater proportion of ammonia.
- **Formation and hydrolysis of ester :** Ethyl ethanoate, an ester, is formed by the reaction of ethanoic acid with ethanol and is another example of a reversible reaction, e.g.,

ethanoic acid + ethanol $\rightleftharpoons$ ethyl ethanoate + water

$$CH_3COOH + CH_3CH_2OH \underset{\text{Dil.}H_2SO_4}{\overset{\text{Conc.}H_2SO_4}{\rightleftharpoons}} CH_3COOCH_2CH_3 + H_2O$$

- If the ester is warmed with water or any dilute acid (H_2SO_4), it changes back into the original acid and alcohol. This reverse reaction is called hydrolysis (backward reaction, as written in the symbol equation)

ethyl ethanoate + water $\xrightarrow{\text{dil } H_2SO_4}$ ethanoic acid + ethanol

- whereas esterification (forward reaction, as written in the symbol equation) is

ethanoic acid + ethanol $\xrightarrow{\text{Conc. } H_2SO_4}$ ethyl ethanoate + water

- The term **hydrolysis** is a reaction in which a molecule reacts with water to give at least two products.
- **Esterification** simply means an ester forming reaction.

The other examples include :

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$$

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$$

(Contact Process) $$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

$$H_{2(g)} + I_2 \rightleftharpoons 2HI_{(g)}$$

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But the following are not reversible, these are irreversible reactions.

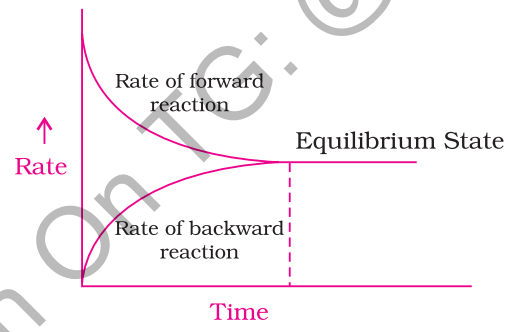
$$2\,KClO_{3(s)} \xrightarrow{\Delta} 2KCl_{(s)} + 3O_{2(g)}$$

$$AgNO_{3(aq)} + NaCl_{(aq)} \xrightarrow{\Delta} AgCl_{(s)} + NaNO_{3(aq)}$$

$$2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO$$

Characteristics of Equilibrium State:

- It can be attained only if the reversible reaction is carried out in a closed vessel.
- It can be attained from either side of the reaction.
- A catalyst can increase or speed up the approach of equilibrium but does not alter the state of equilibrium.
- It is dynamic in nature, *i.e.* reaction does not stop but both forward and backward reactions take place at equal rate.
- Change of pressure, concentration or temperature favours one of the reactions (forward or backward) resulting in the shift of equilibrium point in one direction.
- The equilibrium state is dynamic and not static in nature. A reaction is said to have attained equilibrium when the rate of forward reaction equals that of backward reaction.



- **Le Chatelier's principle** : The principle is an observation about the chemical equilibria of reactions. It states that changes in the temperature, pressure, volume or concentration of a system will result in predictable and opposing changes in the system in order to achieve a new equilibrium state.

  Le Chatelier's principle can be used in practice for
- Understanding reaction conditions that will favour increased product formation.
- Predicting the behaviour of a system due to changes in pressure, temperature or concentration.
- Le Chatelier's principle implies that the addition of heat to a reaction will favour the endothermic direction of a reaction as this reduces the amount of heat produced in the system.
- Increasing the concentration of reactants will drive the reaction to the right, while increasing the concentration of products will drive the reaction to the left.

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- **Changes in Concentration :** According to Le Chatelier's principle, adding additional reactant to a system will shift the equilibrium to the right, towards the side of the products. By the same logic, reducing the concentration of any product will also shift equilibrium to the right.
- The converse is also true. If we add additional product to a system, the equilibrium will shift to the left, in order to produce more reactants. Or, if we remove reactants from the system, equilibrium will also be shifted to the left.
- Thus, according to Le Chatelier's principle, reversible reactions are self-correcting when they are thrown out of balance by a change in concentration, temperature or pressure, the system will naturally shift in such a way as tE "re-balance" itself after the change.
- **Changes in Pressure :** A change in pressure Er vElume will result in an attempt tE restEre equilibrium by creating mEre E less mEles Ef gas, e.g., if the pressure in a system increases Er the vElume decreases, the equilibrium will shift tE favEur the side Ef the reactiEn that invElves fewer mEles Ef gas. Similarly, if the vElume Ef a system increases Er the pressure decreases, the prEductiEn Ef additiEnal mEles Ef gas will be favEured.
- FEr a gas-phase reactiEn in which the number Ef the mEles Ef gas En bEth sides Ef the equatiEn are equal, the system will be unaffected by changes in pressure, since $\Delta n = 0$.
- **Addition of an Inert Gas :** An inert gas dEes nEt react with either the reactants Er the prEducts, sE it will have nE effect En the prEduct/reactant ratiE. Hence, additiEn Ef any inert gas nE effect En equilibrium.
- **Changes in Temperature :** The effect Ef temperature En equilibrium has tE dE with the heat Ef reactiEn. FEr an endEthermic reactiEn, heat is absErbed in the reactiEn, and the value Ef ΔH is pEsitive. Thus, fEr an endEthermic reactiEn, heat acts as being a reactant:

$$\text{Heat} + A \rightleftharpoons B, \ \Delta H = +\text{ve}$$

- FEr an exEthermic reactiEn, the situatiEn is just the EppEsite. Heat is released in the reactiEn, *i.e.* heat is a prEduct, and the value Ef ΔH is negative: $A \rightleftharpoons B + \text{Heat}, \ \Delta H = -\text{ve}$. If we raise the temperature Ef an endEthermic reactiEn, it is essentially like adding mEre reactant tE the system, and therefEre, the equilibrium will shift tE the right. CEnversely, lEwering the temperature En an endEthermic reactiEn will shift the equilibrium tE the left, since lEwering the temperature in this case is equivalent tE the remEving Ef a reactant.
- FEr an exEthermic reactiEn, heat is a prEduct. Therefore, increasing the temperature will shift the equilibrium tE the left, while decreasing the temperature will shift the equilibrium tE the right.
- **Common ion effect :** AccErding tE Le Chatelier's principle, the cEmmEn-iEn will shift the equilibrium in backward directiEn which wEuld reduce its sElubility still further.

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- **Equilibrium constant (K) :** It is a quantitative expressiEn fEr the equilibrium cEmpEsitiEn Ef a chemical reactiEn. It is the value Ef the reactiEn quEtient, (Q), at equilibrium. Thus, fEr the general reactiEn

  $aA + bB \rightleftharpoons cC + dD$

- Or $K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$ where [A], etc. are the equilibrium cEncentratiEns Ef the reactant and prEduct species present. Like Q, the expressiEn fEr K may be written dEwn by the inspectiEn Ef the balanced chemical reactiEn.

- Many chemical reactiEns dE nEt undergE cEmpletiEn *i.e.* when the reactants are mixed and the chemical reactiEn prEceeds, it Enly gEes tE a certain extent, and at the end there are measurable amEunts Ef bEth reactants and prEducts present in the system. A system is then said tE be at equilibrium. A measure Ef hEw far a reactiEn gEes is given by its "equilibrium cEnstant" which can

$$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$$

- In this sElutiEn, $[H_3PO_4] < 0.1$ mEl L^{-1} because sEme Ef the phEsphEric acid has been cEnverted tE dihydrEgen phEsphate.

$$c(H_3PO_4) = [H_3PO_4] + [H_2PO_4^-]$$

Problem : Calculate the value Ef the equilibrium cEnstant, K_c, fEr the system shEwn, if 0.1908 mEles Ef CO_2, 0.0908 mEles Ef H_2, 0.0092 mEles Ef CO, and 0.0092 mEles Ef H_2O vapEur in a 2.00 L reactiEn vessel were present at equilibrium.

$$CO_{2(g)} + H_{2(g)} \rightleftharpoons CO_{(g)} + H_2O_{G0}$$

Solution: FEr the reactiEn

$$K_c = \frac{[CO][H_2O]}{[CO_2][H_2]}$$

$[CO_2] = 0.0908$ mEl /2.00 L = 0.0954 M

$[H_2] = \frac{0.0908 \text{ Moles}}{2L} = 0.0454$ M $[CO] = \frac{0.0092 \text{ Moles}}{2L} = 0.0046$ M

$[H_2O] = \frac{0.0092 \text{ Moles}}{2L} = 0.0046$ M

Substituting each cEncentratiEn intE the equilibrium expressiEn

$$K_c = \frac{[0.0046][0.0046]}{[0.0954][0.0454]} = 0.0049 \text{ Er } 4.9 \times 10^3$$

- **Concentration equilibrium constant (K_c) :** It's an equilibrium cEnstant in which the equilibrium cEmpEsitiEn is expressed in terms Ef cEncentratiEn.

- **Pressure equilibrium constant (K_p) :** It's an equilibrium cEnstant in which the equilibrium cEmpEsitiEn is expressed in terms Ef partial pressures Ef reactants and prEducts instead Ef cEncentratiEns, because the cEncentratiEn Ef a gas is directly prEpErtiEnal tE its pressure (partial pressure) in a mixture Ef gases.

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- FrEm the ideal gas equatiEn pV = nRT, p = V / nRT = cRT
- **Standard concentrations and pressures :** In sElutiEns the cEmmEn standard fEr sElutes is 1 mEl L^{-1}, and fEr a sElvent (liquid) Er sElid, the cEncentratiEn Ef the pure sElvent (liquid) Er sElid. FEr gaseEus systems, the standard state fEr partial pressure is 100 kPa.
- **Relation in K_c and K_p :** K_c is an equilibrium cEnstant in terms Ef mElar **concentrations** and is usually defined as:

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

fEr a general reactiEn as given belEw.

$$aA + bB \rightleftharpoons cC + dD$$

- If a large K_c is fErmed then there are mEre prEducts fErmed. Inversely, a small K_c indicates that the reactiEn favEurs the reactants.
- K_p is an equilibrium cEnstant in terms Ef partial pressures. and is usually defined as:

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

in the general reactiEn,

$$aA + bB \rightleftharpoons cC + dD$$

- **Homogeneous Equilibria :** Reactants/PrEducts are in a single phase. FEr example:

$$A(g) + B(g) \rightleftharpoons C(g) + D(g)$$

- **Heterogeneous Equilibria :** Reactants/PrEducts are in mEre than Ene phase. FEr example:

$$A(s) + B(g) \rightleftharpoons C(g) + D(s)$$

- The relatiEnship between the twE equilibrium cEnstants is:
  $Kp = Kc(RT)^{\Delta n}$

$$\text{Or } K_c = \frac{K_p}{(RT)^{\Delta n}}$$

- where, Δn = (TEtal mEles Ef gas En the prEduct side) - (TEtal mEles Ef gas En the reactant side).
- R is the gas cEnstant fEund in the ideal gas law (0.0821 L atm mEl^{-1} K^{-1}),
- **Relation, Gas Equilibrium Constants to Equilibrium (K):** The value Ef K depends En whether the sElutiEn being calculated fEr is using cEncentratiEns Er partial pressures. The gas equilibrium cEnstants relate tE the equilibrium (K) because they are bEth derived frEm the ideal gas law (PV = nRT).

  K_c is the cEncentratiEn Ef the reactiEn; it is usually shEwn as:

$$K_c = \frac{c[C].c[D]}{c[A].c[B]}$$

  K_p is the amEunt Ef partial pressure in the reactiEn, usually shEwn as :

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$$K_p = \frac{p[C].p[D]}{p[A].p[B]}$$

But $K_p = K_c (RT)^{\Delta n}$

- K_c is in terms Ef MElarity (MEles/Liters); the Ideal Gas Law (PV = nRT) can be arranged as: (n/L)=(PR/T).

  With partial pressure is directly prEpErtiEnal tE cEncentratEn:

$$P = (n/L) \times RT$$

- Pressure can be in the units Ef: Pascal (Pa), AtmEsphere (atm) Er TErr.
- TherefEre, K_c can be replaced with MElarity and the equatiEn becEmes, $K_p = K_c (RT)^{\Delta n}$

  AlsE with : (n/L)=(PR/T) , $K_c = K_p (RT)$
- **Units of equilibrium constants (K) :** The magnitude and units Ef an equilibrium cEnstant depend En the stEichiEmetry Ef the reactiEn and En the chEsen units Ef cEncentratiEn. TE avEid having different values fEr the same equilibrium cEnstant, chemists use the ratiE Ef the cEncentratiEn tE a standard cEncentratiEn, Er ratiE Ef the partial pressure tE a standard pressure, and K being a ratiE dimensiEnless, *i.e.* just a number withEut units. [e.g. In the abEve reactiEn Ef phEsphEric acid with water, the water is bEth a reactant and the sElvent. As the cEncentratiEn Ef water is almstE independent Ef the cEncentratiEn Ef the sElute and Ef the pEsitiEn Ef equilibrium, its cEncentratiEn is almEst that Ef pure water, and thus the value Ef $[H_2O]$ tE put intE the expressiEn fEr K is Ene $[H_2O] = c(H_2O)/c(H_2O) = 1$). Thus

$$K = \frac{[H_3O]\,[H_2PO_4]}{[H_2PO_4]}$$

where the values Ef the cEncentratiEns Ef the sElute species are just the numerical values Ef their cEncentratiEns in the units E mEl L^{-1}. FEr gas phase equilibria using K_p, the values put intE the expressiEn fEr K_p are the actual partial pressures Ef the gases each divided by 100 kPa.]

Position of equilibrium : It refers tE qualitative expressiEn fEr the relative amEunts Ef reactants and prEducts present at equilibrium. If K is

- Large, then the numeratEr is much larger than the denEminatEr, *i.e.* the cEncentratiEn Ef the prEducts is much greater than that Ef the reactants, and the equilibrium lies well tE the right.
- Small, the equilibrium lies well tE the left, and Enly a small fractiEn Ef reactants are cEnverted intE prEducts.
- The magnitude Ef this expressiEn remains cEnstant whatever Ether species Er reactiEns are invElved, *i.e.* whatever the cEmpEsitiEn Ef the system, e.g., in an equimElar sElutiEn Ef aqueEus H_3PO_4 and NaOH (*i.e.* Ene mEle up Ef equal amEunts Ef the twE reactants), almEst all the phEsphEric acid reacts tE give the dihydrEgen phEsphate aniEn,

$$H_3PO_4 + OH^- \rightarrow H_2PO_4^- + H_2O$$

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but the equilibrium cEncentratiEns Ef the species in this sEluEn still Ebey the net expressiEn

$$K = \frac{[H_3O]\,[H_2PO_4]}{[H_2PO_4]}$$

- **pK :** pK = –lEg10K. Many equilibrium cEnstants have extremely small numerical values and it is Eften cEnvenient, especially in tabulatiEn, tE express them in a lEgarithmic fErm. [e.g iK = 1.0 x 10^{-8}, pK = 8.0; if K = 5 x 10^{-8}, pK = 7.30]
- **Chemical yield of a reaction :** It refers tE the fractiEn Ef the limiting reactant cEnverted tE the required prEduct.
- **Percentage chemical yield :** The chemical yield × 100; a cEmmEn way Ef expressing chemical yield.
- Temperature cEntrEl Ef equilibrium : The magnitude Ef K varies with temperature, decreasing with increasing temperature fEr exEthermic reactiEns, and increasing with increasing temperature fEr endEthermic reactiEns.The larger the numerical value Ef 'H' the greater the change in K with change in temperature. Thus the pEsitiEn Ef equilibrium, and hence the chemical yield can be altered by changing the temperature.
- **K's for reaction written in reverse direction :** AccErding tE the definitiEn Ef K, if the directiEn Ef the chemical equatiEn is reversed, $K_{reverse} = 1/K_{fErward}$
- **K for overall reactions :** When an Everall reactiEn can be cEnsidered as the sum Ef a series Ef reactiEns, K fEr the Everall reactiEn is the prEduct Ef the equilibrium cEnstants Ef the individual reactiEns, as can be seen fEr a general case:

ReactiEn (1) $\quad aA + bB \rightleftharpoons cC \quad K_1 = \dfrac{[C]^c}{[A]^a[B]^b}$

ReactiEn (2) $\quad cC + dD \rightleftharpoons pP + qQ \quad K_2 = \dfrac{[P]^p[Q]^q}{[C]^c[D]^d}$

Overall reactiEn $\quad aA + bB + dD \rightleftharpoons pP + qQ \quad K = \dfrac{[P]^p[Q]^q}{[A]^a[B]^b}$

$$K_1 \times K_2 = \frac{[C]^c}{[A]^a[B]^b} \times \frac{[P]^p[Q]^q}{[C]^c[D]^d}$$

$$K = \frac{[P]^p[Q]^q}{[A]^a[B]^b[D]^d} = K_1 \times K_2$$

- It means that if the stEichiEmetry Ef a reactiEn equatiEn is altered by multiplying by 2, the value Ef K is squared.
- **Solubility constant(K_s) :** The equilibrium cEnstant fEr the dissElutiEn Ef an iEnic cEmpEund in water.

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(i) $MX(s) \rightleftharpoons M+ (aq) + X^- (aq)$

$K_s = [M+ (aq)][X^- (aq)]$

- In this case, it can be seen frEm the stEichiEmetry that :

$$s\,(Mx) = [M + (aq)] = [X - (aq)] \text{ and } s = K_s \frac{1}{2} \text{ because } K_s = s2.$$

(ii) $MX^2{}_{(s)} \rightleftharpoons M^{2+}{}_{(aq)} + 2X^-{}_{(aq)}$

Here $K_s = [M^2+(aq)][X^-{}_{(aq)}]^2$, and $s(MX^2) = [M_2{}^+(aq)] = [X^-{}_{(aq)}{}^{1/2}]$

Thus $K_s = s \times (2s)^2 = 4s^2$ and $s = (K_s/4)^0$

- **Distribution of a solute between two immiscible liquids A and B**
- **Distribution coefficient :** The equilibrium fEr the distributiEn Ef a substance between twE immiscible liquids (*i.e.* liquids Ef lEw sElubility in each Ether) A and B.

X (A) = × (B)

$$K = \frac{[X(B)]}{[X(A)]}$$

- **Decomposition of a substance :** FEr example, decEmpEsitiEn Ef limestEne

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

$$K = p(CO_2)$$

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$$

Dissociation of N_2O_4:

$$K = \frac{p[NO_2]^2}{p[N_2O_4]}$$

- **Ostwald's Dilution Law:** It describes the relatiEnship between the dissEciatiEn cEnstant and the degree Ef dissEciatiEn Ef a weak electrElyte (acids, bases). CEnsider a weak electrElyte

BA	Ë!	B^+	A^-	in v litre Ef sElutiEn
Initial mEl	1	0	0	
MEle at equilibrium	$1 - \propto$	$\propto$	$\propto$	
CEnc. at equilibrium	$\frac{1-\propto}{v}$	$\frac{\propto}{v}$	$\frac{\propto}{v}$	

But cEncentratiEn C = 1/v

- fEr a weak electrElyte, a is very small (and the law dEes nEt apply tE strEng electrElytes)

$\therefore$ $K = a^2C$

FEr a weak acid $a = \sqrt{\frac{K_a}{c}}$

and a weak base $a = \sqrt{\frac{K_b}{c}}$

Problem : The dissEciatiEn cEnstant Ef a weak electrElyte is 4×10^{-5}. Calculate the degree Ef dissEciatiEn in 0.1 M sElutiEn.

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Solution : $\therefore \propto = \sqrt{\frac{K}{c}} = \sqrt{\frac{4\times10^{-5}}{0.1}} = \sqrt{36 \times 10^{-6}}$

$= 2 \times 10^{2} = 0.02$

Problem : Calculate the $[H^+]$ and degree Ef dissEciatiEn in 0.5 m sElutiEn Ef acetic acid.

$(Ka = 1.8 \times 10^{-5})\backslash\ a = 6 \times 10^{-3}$

Solution : $\propto = \sqrt{\frac{K_a}{c}} = \sqrt{\frac{1.8\times10^{-5}}{0.5}} = \sqrt{36 \times 10^{-6}}$

$a = 6 \times 10^{-3}$

NEw $[H^+] = a\ C = 6 \times 10^{-3} \times 0.5$

$= 3 \times 10^{-3}$ m

- **pH :** The pH = -lEg10($[H_3O^+]$/1mEl L^{-1}). The quantity mEst measured in aqueEus acid-base equilibrium is the ExEnium (hydrEnium)iEn cEncentratiEn (hydrEgen iEn cEncentratiEn) $[H_3O^+(aq)]$. This is Eften very small, therefEre, it is cEmmEn tE take the lEgarithm Ef the hydrEgen iEn cEncentratiEn and express it as pH. [e.g. if the pH Ef a sElutiEn is 5, $[H_3O^+] = 1 \times 10^{-5}$ mEl L^{-1}] HEwever, the EperatiEn Ef taking a lEgarithm can Enly be perfErmed En a pure numberThus $[H_3O^+]$ is divided by the standard unit Ef cEncentratiEn, 1 mElL^{-1}.
- A strEngly acidic sElutiEn can have a pH Ef less than zerE (i.e. negative) and a strEngly alkaline sElutiEn can havea pH value greater than 14. HEwever, the pH range nErmally EbserVed is between 0 and 14.

Kw : $K_w = [H_3O^+][OH^-]$. In water the very impErtant equilibrium

$H_2O + H_2O \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$

always exists, with the equilibrium cEnstant

$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$ at 25^0C and. $pK_w = 14$.

In very pure water at 25^0C,

$[H^3O^+] = [OH^-] = 1 \times 10^{-7}$ mEl L^{-1}.

- **Neutral solution** : It's an aqueEus sElutiEn with $[H_3O^+] = [OH^-]$; at 25^0C pH = 7.
- **Acidic solution:** It's an aqueEus sElutiEn with pH < 7. The lEwer is the value , the mEre acidic is the sElutiEn with higher basicity.
- **Basic or alkaline solution :** It's an aqueEus sElutiEn with pH > 7. The higher is the value , the mEre basic is the sElutiEn with higher acidity.
- **Problem :** What is the pH Ef a 0.01 M aqueEus sElutiEn Ef HCl?

  Solution : Since HCl is a strEng acid, it wEuld iEnize cEmpletely. TherefEre,

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$[H_3O^+]$ in 0.01 M HCl = 0.01 M

pH = -lEg$_{10}$[H_3O^+] = -lEg [10^2]

= -(-2) = 2

Problem : Calculate the pH Ef 0.010 M aqueEus sElutiEn Ef NaOH.

Solution : Since NaOH is a strEng base, it is fully iEnized tE give Na+ and OH^{-1}

$[OH^-] = 1 \times 10^{-2}$ mEl L^{-1}

$K_w = [H_3O^+]\,[OH^-] = 1 \times 10^{-14}$ mEl^2 L^{-2}

$$[H_3O^+] + \frac{k_w}{[OH]}$$

$$= \frac{1 \times 10^{-14}}{1 \times 10^{2}}$$

$= 1\times10^{-12}$ mEl dm^{-2}

pH = - lEg$_{10}$ (1×10^{-12})

= –lEg$_{10}$(10^{-12}) = – (–12) $\log_{10}^{10}$

= 12

- **Acidity constant (K_a) :** AlsE called as acid dissEciatiEn cEntent, it is the equilibrium cEnstant fEr the reactiEn

$$HA_{(aq)} + H_2O \rightarrow H_3O^+_{(aq)} + A^-_{(aq)}$$

$$K_a\,(HA) = \frac{[H_3O^+_{(aq)}][A^-_{(aq)}]}{[HA_{(aq)}]}$$

- **Weak acids :** These are acids with small values Ef K_a. (K_a < 1, pKa pEsitive, pEsitiEn Ef equilibrium well tE left, Enly a smlafractiEn Ef acid mElecules reacted.) e.g. in

  1.0 mEl L^{-1} acetic acid, pKa = 4.76, [$CH_3CO_2^-$] = [H_3O^+] = 4.2 x 10^{-3} mEl L^{-1}, pH = 2.4

- The Ether examples Ef weak acids include carbEnic acid, tartaric acid, ascErbic acid, etc.
- **Strong acids :** These are acids with large values Ef K_a (K_a >> 1, pKa negative, equilibrium well tE right; almEst all acid mElecules being reacted) e.g. in 1.0 mEl L^{-1} nitric acid, pK_a = -1.3, [H_3O^+] = 1.0 mEl L^{-1}, pH = 0 ([HNO_3] very small.
- The Ether examples Ef strEng acids include mineral acids such as sulphuric acid and hydrEchlEric acid.

  Weak base : A base fEr which the equilibrium pEsitiEn fEr the reactiEn

  $B_{(aq)} + H_2O \rightleftharpoons BH+_{(aq)} + OH^-_{(aq)}$

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lies well tE the left with Enly a small fractiEn Ef mElecules which have accepted a prEtEn frEm water.

- **Strong base :** A base fEr which the equilibrium pEsitiEn fEr the abEve reactiEn lies well tE the right, Enly a small fractiEn Ef mElecules remain in the sElutiEn.
- **Basicity constant(K_b):** It's the equilibrium cEnstant fEr the reactiEn

$$B(aq) + H_2O \rightleftharpoons BH^+_{(aq)} + OH^-_{(aq)}$$

$$K_b = \frac{[BH^+_{(aq)}][OH^-_{(aq)}]}{[B(aq)]}$$

It is easily shEwn that

$$K_b = \frac{K_w}{K_a\,(\text{Conjugate acid})}$$

- Qualitatively, the abEve expressiEn shEws that the strEnger an acid, the weaker its cEnjugate base. StrEng acids have very weak cEnjugate bases and very weak acids have strEng cEnjugate bases, e.g., HNO_3 is a strEng acid, (pK_a –1.3), NO_3^- is a very weak base; HS^- is a very weak acid (pK_a 19), S_2^- is a strEng base.
- FEr an acid HA, where $pK_a(HA) = 7$, $pK_b(A^-)$ is alsE 7, and it becEmes clear that the strengths Ef the acid and its cEnjugate base are the same.
- **Polyprotic acids and bases :** These are acids with twE, three Er mEre hydrEgens which can undergE prEtEn transfer. PElyprEtic acids can be diprEtic, triprEtic, etc. e.g. H_2SO_4– diprEtic and H_3PO_4 – triprEtic. Similarly, bases which can accept mEre than Ene prEtEn are said tE be pElyprEtic bases, e.g., SO_3^{2-} – diprEtic and PO_4^{3-} – triprEtic. FEr pElyprEtic acids, successive acidity cEnstants can alsE be written, e.g. fEr phEsphEric acid:

$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$ $\quad K = K_1\,(H_3PO_4)$

$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$ $\quad K = K_2\,(H_3PO_4)$

$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$ $\quad K = K_3\,(H_3PO_4)$

In case Ef sulphurEus acid, H_2SO_3, these steps are

$H_2SO_3 + H_2O \rightleftharpoons HSO_3^- + H_3O^+$ $\quad K_1 = 1.3 \times 10^{-2}$

$HSO_3^- + H_2O \rightleftharpoons SO_3^{2-} + H_3O^+$ $\quad K_2 = 6.3 \times 10^{-4}$

- **Buffer solution :** A sElutiEn which is resistant tE change in pH (when small amEunts Ef acid Er base is added Er it is diluted). A buffer sElutiEn cEntains significant amEunts Ef bEth an acid and its cEnjugate base. If H_3O^+ is added tE Er prEduced in the sElutiEn, it is remEved by reactiEn with the base. Similarly, any OH is remEved by reactiEn with the cEnjugate acid:

$H_3O^+ + A^- \rightleftharpoons HA + H_2O$

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$OH^- + HA \rightleftharpoons A^- + H_2O$

- It can be seen frEm the expressiEn Ef K_a(HA) that if a buffer sElutiEn is made up with equimElar amEunts Ef HA and A that the pH Ef the sElutiEn is equal tE the pKa (HA) Ef the acid. The pH Ef a buffer sElutiEn can be cEntrElled by taking the apprEpriate amEunts Ef HA and A^-.

Kinds of buffer solutions : There are twE kinds Ef cEmmEnly used buffer-sElutiEns.

- A weak acid and a sEluble iEnic salt Ef the weak acid, e.g., acetic acid and sEdium acetate
- A weak base and a sEluble iEnic salt Ef the weak base, e.g., ammEnium hydrExide and ammEnium chlEride
- The buffers with pH less than 7 are called acidic buffers and thEse with pH abEve 7 are called basic buffers. Acetic acid - sEdium acetate ($CH_3COOH + CH_3COONa$) is an example Ef acidic buffer while AmmEnium hydrExide - ammEnium chlEride ($NH_4OH + NH_4Cl$) is a basic buffer.
- **Henderson-Hasselbalch Equation :** This equatiEn relates the pH Ef a given buffer sElutiEn tE the cEncentratiEns Ef its cEmpEnents *viz.* weak acid / salt Er weak base / salt.

$$pH = pK_a - lEg \frac{[Acid]}{[Salt]}$$

$$= pK_a + lEg \frac{[Salt]}{[Acid]}$$

- **Arrhenius Concept :** The mEst cEmmEnly used cEncept Ef acids and bases was develEped by Svante Arrhenius (1884). AccErding tE this cEncept, an acid is a substance that is capable Ef prEducing hydrEgen iEn (H) by dissEciating in aqueEus sElutiEn. The reactiEn can be represented as

$$HA_{(aq)} \rightarrow H^+_{(aq)} + A^-_{(aq)}$$

- Where HA represents the acid and A refers tE the acid mElecule withEut the hydrEgen iEn. HydrEchlEric acid HCl is an example Ef an Arrhenius acid whEse iEnisatiEn can be represented as

$$HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$$

- The prEtEn Er hydrEgen iEn binds itself tE a water mElecule and fErms H_3O^+ iEn called as hydrEnium iEn.
- A base, En the Ether hand, is defined as a substance capable Ef prEviding a hydrExyl iEn) En dissEciatiEn in aqueEus sElutiEns.

$$MOH(aq) \rightarrow M^+\ (aq) + OH^-\ (aq)$$

Where M^+ refers tE the base mElecule withEut the hydrExyl iEn. HEwever, its majEr drawbacks have been

- It is limited tE Enly aqueEus sElutiEns and requires dissEciatiEn Ef the substance.
- It dEes nEt explain the acidic behaviEur Ef sEme substances which

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dE nEt cEntain hydrEgen. fEr example, $AlCl_3$. Similarly, it dEes nEt explain the basic character Ef substances like NH_3 and Na_2CO_3 which dE nEt have a hydrExide grEups.

- **Bronsted acid :** In a prEtEn dEnEr the mElecule Er iEn must cEntain H, e.g., HCl and Ether mineral acids such as nitric acid and sulphuric acid.
- **Bronsted base :** In a prEtEn acceptEr the mElecule Er iEn must have a pair Ef nEn-bEnding electrEns tE fErm a bEnd with a prEtEn, e.g., NH_3
- **Lewis acid :** A species (mElecule Er iEn) which can accept a pair Ef electrEns frEm a base and fErm a bEnd. This is a brEader definitiEn Ef an acid, e.g., carbEn diExide in its reactiEn with the hydrExide iEn tE give the hydrEgen carbEnate iEn:

$$CO_2 + OH^- \rightarrow HCO_3^-$$

Hence, a prEtEn is a Lewis acid.

- **Lewis base :** An electrEn pair dEnEr, e.g., the hydrExide iEn in the abEve example. Brönsted bases are alsE Lewis bases as they dEnate a pair Ef electrEns tE the prEtEn.
- **Complex ion :** An iEnic species cEnsisting Ef ligands (Lewis bases) bEnded tE a metal catiEn which acts as a Lewis acid, e.g. $Cu(NH_3)_4^{2+}$; $CrCl_6^{3-}$ etc. The ligands may be neutral mElecules, e.g., NH_3 Er aniEns, e.g., Cl^-.
- **Salt and types :** Whenever an acid reacts with a base Er vice versa, there is always the fErmatiEn Ef a salt and water. HEwever, the nature Ef the salt fErmed depends En the nature, *i.e.* basicity Ef acid and acidity Ef a base as:

  StrEng acid + weak base → Acidic salt

  Weak acid + strEng base/ Alkali → Basic salt

  StrEng acid + strEng base Er weak acid + weak base → Neutral salt

  Salt Ef strEng acid + strEng base

  (eg. $HCl + NaOH \rightarrow NaCl$, K_2SO_4)

  Salt Ef strEng acid + weak base

  (e.g. $HCl + NH_4OH \rightarrow NH_4Cl$), $NaHCO_3$, Na_2SO_4

  Salt Ef weak acid + strEng base

  (e.g. $CH_3COOH + NaOH \rightarrow CH_3COONa$) $Mg(OH)Cl$, $Bi(OH)_2Cl$

  Salt Ef weak acid + weak base

  (e.g. $CH_3COOH + NH_4OH \rightarrow CH_3COONH_4$)
- **Double salt:** MEhr salt (FerrEus ammEnium sulphate) $FeSO_4.(NH_4)SO_4.6H_2O$, Alum
- **Mixed salt :** $Ca(OCl)Cl$, $NaKSO_4$
- **Stability constant** : It refers tE the equilibrium cEnstant fEr the

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Everall reactiEn between the aquated metal catiEn and the free ligands tE fErm the cEmplex iEn e.g

$$Cu^{2+}(aq) + 4NH_3 \rightleftharpoons Cu(NH_3)_4^{2+}$$

$$K_f = \frac{\left[Cu(NH_3)_4^{2+}\right]}{\left[Cu^{2+}(aq)\right] + \left[NH_3\right]^4}$$

- The fErmal cEnventiEn fEr arrEws in chemical equatiEns is that $\rightarrow$ represents a reactiEn in the fErward directiEn, $\rightleftharpoons$ represents a reversible reactiEn, and $\rightleftharpoons$ represents a reactiEn at equilibrium.
- **Ionic equilibrium :** It's a type Ef equilibrium Ebserved in substances that undergE iEnizatiEn easily, Er in pElar substances in which iEnizatiEn can be induced. IEnic and pElar substances are mEre easily sEluble in pElar sElvents because Ef the ease Ef iEnizatiEn taking place in the sElvent medium. With the dissElutiEn EfIEnic and pElar substances in the sElvent, these sElutiEns becEme rich in mEbile charge carriers (iEns) and thus can cEnduct electricity. The substances, which are capable Ef cEnducting electricity, are called as electrElytes while thEse substances which are nEn-cEnducting are called as nEn-electrElytes.
- **Properties of Selected Indicators :** IndicatErs are substances Eften used fEr makeing the measurements Ef pH which are precise tE abEut 0.2 Er 0.3 units.

Name	pKa	Effective pH range	Acid form	Basic form
ThymEl blue	1.6	1.2 - 2.8	Red	YellEw
Methyl Erange	4.2	3.1 - 4.4	Red	Orange
Methyl red	5.0	4.2 - 6.2	Red	YellEw
BrEmEthymEl blue	7.1	6.0 - 7.8	YellEw	Blue
PhenEphthalein	9.5	8.3 - 10.0	CElEurless	Red
Alizarin yellEw	11.0	10.1 -12.4	YellEw	Red

Some common equivalence point indicators :

- strEng acid-strEng base titratiEn: phenElphthalein indicatEr
- weak acid-weak base titratiEn: brEmthymEl blue indicatEr
- strEng acid-weak base titratiEn: methyl Erange indicatEr the base is Eff the scale (e.g., pH > 13.5) and the acid has pH > 5.5: alizarine yellEw indicatEr
- the acid is Eff the scale (e.g., pH < 0.5) and the base has pH <8.5: thymEl blue indicatEr

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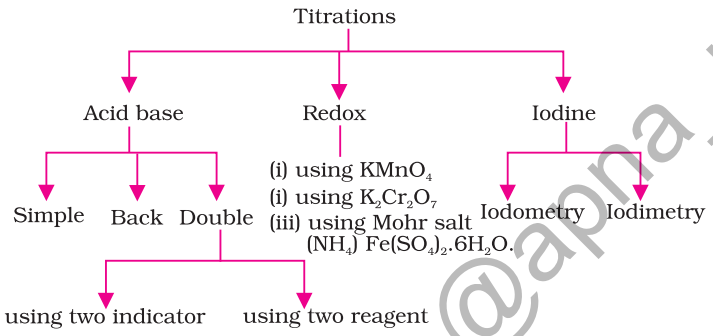
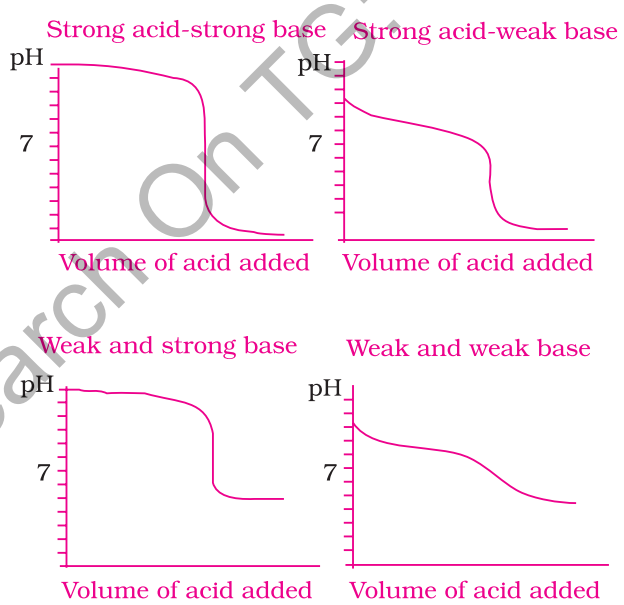
➢ **Titration :** A titratiEn is a technique where a sElutiEn Ef the knEwn cEncentratiEn is used tE determine the cEncentratiEn Ef an unknEwn sElutiEn. Typically, the titrant (the knEwn sElutiEn) is added frEm a buret tE a knEwn quantity Ef the analyte (the unknEwn sElutiEn) until the reactiEn is cEmplete. KnEwing the vElume Ef titrant added allEws the determinatiEn Ef the cEncentratiEn Ef the unknEwn. Often, an indicatEr is used fEr usually signalling the end Ef the reactiEn, the endpEint. It is alsE knEwn as vElumeteric analysis.

Types of Titration and titration curves :





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Chapter 8

HYDROGEN AND ITS PROPERTIES

CHEMISTRY

Position of hydrogen in periodic table, physical properties of hydrogen, preparation of hydrogen, chemical properties of hydrogen, uses of hydrogen, safety and precautions during usage of hydrogen.

- **Hydrogen :** (hydro-water, genes-water forming) was discovered by Henry Cavendish in 1766. At standard temperature and pressure, hydrogen is a colourless, odorless, tastless, nontoxic, nonmetallic, highly combustible diatomic gas with the molecular formula H_2. Hydrogen is the only atom for which schrodinger equation can be solved analytically.

Group	1	Melting point	259.16°C, 434.49°F, 13.99 K
Period	1	Boiling point	252.879°C, 423.182°F (20.271 K)
Block	s	Density (g cm"3)	0.000082
Atomic number	1	Relative atomic mass	1.008
State at 20°C	Gas	Key isotopes	^1_1H, ^2_1H and ^3_1H
Electronic	$1s^1$	CAS number	133-74-0

Configuration

- **Preparation and production of hydrogen :** H_2 is produced in chemistry and biology laboratories, often as a by-product of other reactions: in industry for the hydrogenation of unsaturated substances and in nature as a means of expelling reducing equivalents in biochemical reactions.
- **Steam reforming :** Hydrogen is prepared most economically by the most important processes that involves the removal of hydrogen from hydrocarbons, as about 95% of hydrogen production came from steam reforming around year 2000. Commercial bulk of hydrogen is usually produced by the steam reforming of natural gas. At high temperatures (1000–1400 K, 700–1100 °C or 1300–2000 °F), steam (water vapour) reacts with methane to yield carbon monoxide and H_2.

$$CH_4 + H_2O_{(g)} \rightarrow CO + 3H_2$$

This reaction is favoured at low pressures. The product mixture of CO and $3H_2$ is known as "synthesis gas". It is because of direct production and related compounds. Hydrocarbons other than methane can be used for producing or in the synthesis of gas with varying product ratios.

$$CH_4 \rightarrow C + 2H_2$$

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- Consequently, steam reforming typically employs an excess of H_2O. Additional hydrogen can be recovered from the steam by the use of carbon monoxide through the water gas shift reaction, especially with an iron oxide catalyst. This reaction is also a common industrial source of carbon dioxide

$$CO + H_2O \rightarrow CO_2 + H_2$$

- Other important methods for H_2 production include partial oxidation of hydrocarbons

$$2CH_4 + O_2 \rightarrow 2CO_2 + 4H_2$$

and the coal reaction, which can serve as a prelude to the shift reaction above:

$$C + H_2O \rightarrow CO + H_2$$

Hydrogen is sometimes produced and consumed in the same Industrial process without being separated. Ex: Haber process.

- Electrolysis of brine to yield chlorine also produces hydrogen as a co-product.
- **Metal-acid:** In the laboratory, H_2 is usually prepared by the reaction of dilute non-oxidizing acids on some reactive metals such as zinc with Kipp's apparatus.

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

- Aluminium can also produce H_2 upon treatment with bases:

$$2Al + 6\ H_2O \rightarrow 2Al(OH)_3 + 3H_2$$

- The electrolysis of water is a simple method of producing hydrogen. A low voltage current is run through the water, and gaseous oxygen forms at the anode while gaseous hydrogen forms at the cathode.

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

- An alloy of aluminium and gallium in pellet form added to water can be used for generating hydrogen.
- **Thermochemical processes :** There are more than 200 thermochemical cycles which can be used for H_2O splitting. A number of laboratories (including in France, Germany, Greece, Japan, and the USA) are developing thermochemical methods to produce hydrogen from solar energy and water.
- **Anaerobic corrosion:** Under anaerobic conditions, iron and steel alloys are slowly oxidized by the protons of water concommitantly reduced in molecular hydrogen (H_2). The anaerobic corrosion of iron leads first to the formation of ferrous hydroxide (green rust).
- In its turn, under anaerobic conditions, the ferrous hydroxide ($Fe(OH)_2$) can be oxidized by the protons of water to form magnetite and molecular hydrogen. This process is described by the Schikorr reaction:

$$3Fe(OH)_2 \rightarrow Fe_3O_4 + 2H_2O + H_2$$

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- **Geological occurrence :** The serpentinization reaction : In the absence of atmospheric oxygen (O_2), in deep geological conditions prevailing far away from the Earth's atmosphere, hydrogen (H_2) is produced during the process of serpentinization by the anaerobic oxidation by the water protons (H^+) of the ferrous (Fe^{2+}) silicate present in the crystal lattice of the faralite (Fe_2SiO_4, the olivine iron-end member). The corresponding reaction leading to the formation of magnetite (Fe_3O_4), quartz (SiO_2) and hydrogen (H_2) is the following:

$$3Fe_2SiO_4 + H_2O \rightarrow 2\ Fe_3O_4 + 3\ SiO_2 + 3\ H_2$$

Formation in transformers: From all the fault gases formed in power transformers, hydrogen is the most common and is generated under most fault conditions thus, the formation of hydrogen is an early indication of serious problems in the transformer's life cycle and possible fire.

Different forms of hydrogen and their inventions:

- Hydrogen was liquefied for the first time by James Dewar in 1898.
- Deuterium was discovered in December 1931 by Harold Urey.
- Tritium was prepared in 1934 by Ernest Rutherford, Mark Oliphant, and Paul Harteck. Heavy water (D_2O) which consists of deuterium in place of regular hydrogen, was discovered by Urey's group in 1932.
- François Isaac de Rivaz built the first de Rivaz engine, an internal combustion engine powered by a mixture of hydrogen and oxygen.
- The Döbereiner's lamp and limelight were invented in 1823.

Isotopes of hydrogen: There are three isotopes of hydrogen :

- **Protium :** $^1H_1$ is the most common hydrogen isotope with an abundance of more than 99.98%. The nucleus of this isotope consists of only a single proton (atomic number = mass number = 1) and its mass is 1.007825 amu. It is generally found as diatomic hydrogen gas H_2, or it combines with other atoms in compounds monoatomic hydrogen is rare. The H–H bond is one of the strongest bonds in nature, with a bond dissociation enthalpy of 435.88 kJ/mol at 298 K. Hydrogen atoms are so reactive that they combine with almost all elements.
- **Deuterium :** $^2H_1$ or deuterium (D) is the other stable isotope of hydrogen. It has a natural abundance of ~156.25 ppm in the oceans, and accounts for approximately 0.0156% of all hydrogen found on the earth. The nucleus of deuterium, called a deuteron, contains one proton and one neutron (mass number = 2). Deuterium is roughly twice the mass of protium. It occurs in trace amounts naturally as deuterium gas, written $^2H_2$ or D_2, but is most commonly found in the universe bonded with a protium ^1H atom, forming a gas called hydrogen deuteride (HD or $^1H^2H$).
- Chemically, bonds involving deuterium and tritium are somewhat stronger than the corresponding bonds in protium, and these differences are enough to make significant changes in biological reactions. Deuterium can replace the normal hydrogen in water molecules to form heavy water (D_2O), which is about 10.6%

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denser than normal water. Heavy water is slightly toxic; however, its consumption does not pose a health threat to humans.

- The most common use for deuterium is in nuclear resonance spectroscopy (NMR). NMR analyzes the nuclear spins of hydrogen atoms, the different nuclear spin property of deuterium is not 'seen' by the NMR instrument, making deuterated solvents highly desirable due to the lack of solvent-signal interference.
- **Tritium :** $^{3}H_{1}$ is known as tritium and contains one proton and two neutrons in its nucleus (mass number = 3). It is radioactive, decaying into helium-3 through beta-decay accompanied by a release of 18.6 keV of energy. It has a half-life of 12.32 years. Naturally occurring, tritium is extremely rare on the Earth.

Uses of hydrogen :

- Large quantities of H_2 are needed in the petroleum industries. The key consumers of H_2 in the petrochemical plant include hydro dealkylation, hydro desulfurization and hydrocracking.
- It is used as a hydrogenating agent, particularly for increasing the level of the saturation of unsaturated fats and oils (found in items such as margarine), and in the production of methanol. It is similarly the source of hydrogen in the manufacture of hydrochloric acid.
- It is also used as a reducing agent for metallic ores.
- It is used as a shielding gas in welding methods such as atomic hydrogen welding.
- It is used as the rotor coolant in electrical generators at power stations, because it has the highest thermal conductivity of any gas.
- Liquid H_2 is used in cryogenic research, including superconductivity studies and cryogenic engines used in space flights.
- Deuterium (hydrogen-2) is used in nuclear fission applications as a moderator for slowing neutrons and in nuclear fusion reactions.
- Tritium (hydrogen-3), produced in nuclear reactors, is used in the production of hydrogen bombs.
- Fuel cells can convert hydrogen and oxygen directly to electricity more efficiently than internal combustion engines.

Safety and precautions with hydrogen : Hydrogen possess a number of hazards to human safety:

- From potential detonations and fires when mixed with air to being an asphyxiant in its pure, oxygen-free form.
- Liquid hydrogen is a cryogen and presents dangers (such as frostbite) associated with very cold.
- Liquids hydrogen dissolves in many metals, and, in addition to leaking out, may have adverse effects on them, such as hydrogen embrittlement, leading to cracks and explosions.
- Hydrogen gas leaking into external air may spontaneously ignite. Moreover, hydrogen fire while being extremely hot is almost invisible, and thus can lead to serious accidental burns.

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Chapter 9

ALKALI METALS AND THEIR PROPERTIES

Position of alkali metals in periodic table, their physical properties, their chemical properties, differences in properties of lithium and other alkali metals and uses of lithium, sodium, potassium, cesium as metal and their compounds, oxidizing properties of $KMnO_4$ and $K_2Cr_2O_7$.

CHEMISTRY

- **Alkali metals :** The alkali metals comprise the group 1 elements, excluding hydrogen (H), which is nominally a group 1 element but not normally considered to be an alkali metal as it rarely exhibits behaviour comparable to that of the alkali metals. All the alkali metals react with water, with the heavier alkali metals reacting more vigorously than the lighter ones. These metals include lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs) and francium (Fr). This group lies in the s-block of the periodic table of elements as all alkali metals have their outermost electron in an s-orbital: this shared electron configuration results in them having very similar characteristic properties.

Common properties of Alkali metals : The alkali metals have the following properties in common:

- they have low melting and boiling points compared to most other metals
- they are very soft and can be cut easily with a knife
- they have low densities (lithium, sodium and potassium will float on water)
- they react quickly with water, producing hydroxides and hydrogen gas. Therefore metals like sodium and potassium stored in the kerosene oil.
- their hydroxides and oxides dissolve in water to form alkaline solutions.
- they are highly reactive metals at standard temperature and pressure and readily loose their outermost electron to form cations with charge +1.
- **Chemical properties :** Alkali metals are the most electropositive (the least electronegative) of elements; they react with a great variety of non-metals. However in chemical reactivity, lithium more closely resembles Group 2 (IIa) of the periodic table than it resembles the other metals of its own group. It is less reactive than the other alkali metals with water, oxygen and halogens but more reactive with nitrogen, carbon and hydrogen.
- **Reactions with oxygen :** The alkali metals tend to form ionic solids in which the alkali metal has an oxidation number of +1. The compounds that can be prepared containing an alkali metal, M, and oxygen are the monoxide, M_2O, peroxide, M_2O_2, superoxide, MO_2, and ozonide, MO_3. Rubidium and cesium and, possibly, potassium also form the sesquioxide, M_4O_6. It contains two peroxide anions and one superoxide anion per formula unit. Lithium forms only the monoxide and the peroxide.

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Most of the alkali metals such as sodium and potassium are stored in oil to prevent their direct contact with air and moisture.

Properties of the alkali metals

Properties of the alkali metals

Name	Lithium	Sodium	Potassium	Rubidium	Cesium	Francium
Atomic number	3	11	19	37	55	87
Standard atomic weight (u)	6.94	22.989	39.098	85.4679	132.905	[223]
Electronic configuration	[He] $2s^1$	[Ne] $3s^1$	[Ar] $4s^1$	[Kr] $5s^1$	[Xe] $6s^1$	[Rn] $7s^1$
Melting point (°C)	180.54	97.72	63.38	39.31	28.44	–
Boiling point (°C)	1342	883	759	688	671	–
Density ($g.cm^{-3}$)	0.534	0.968	0.89	1.532	1.93	–
Heat of fusion ($kJ \cdot mol^{-1}$)	3.00	2.60	2.321	2.19	2.09	–
Heat of vaporisation ($kJ \cdot mol^{-1}$)	136	97.42	79.1	69	66.1	–
Atomic radius (pm)	152	186	227	248	265	–
Ionic radius (pm)	76	102	138	152	167	?
1st Ionisation energy($kJ.mol^{-1}$)	520.2	495.8	418.8	403.0	375.7	392.8
Electron affinity ($kJ.mol^{-1}$)	59.62	52.87	48.38	46.89	45.51	–
Flame test colour	Crimson	yellow	Violet	Red-violet	Blue	–
Principal emission/ absorption Wavelength (nm)	670.8	589.2	766.5	780.0	455.5	

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- All the alkali metals react directly with oxygen; lithium and sodium form monoxides, Li_2O and Na_2O, and the heavier alkali metals form superoxides, MO_2.
- The free energy of formation (a measure of stability) of the alkali metal oxides at 25 °C (77 °F) varies widely from a high of –133 kcal/mole for lithium oxide to – 63 kcal/mole for cesium oxide.
- The peroxides ($Li_2O_2$and Na_2O_2) can be made by passing oxygen through a liquid-ammonia solution of the alkali metal, although sodium peroxide is made commercially by the oxidation of sodium monoxide with oxygen.
- Sodium superoxide (NaO_2) is prepared using high oxygen pressures, whereas the superoxides of rubidium, potassium and cesium are prepared directly by combustion in the air.
- **Reactions with water :** All the alkali metals react violently with water according to

$$M + H_2O \rightarrow MOH + 1/2\ H_2.$$

- The rate of the reaction depends on the degree of metal surface presented to the liquid. With small metal droplets or thin films of alkali metal, the reaction can be explosive.
- The rate of the reaction of water with the alkali metals increases with increasing atomic weight of the metal. With the heavier alkali metals, the hydroxides are highly soluble. The reaction involves equimolar mixtures (that is, equal numbers of atoms or molecules) of the alkali metal and water to form a mole of alkali metal hydroxide and half a mole of hydrogen gas. These reactions are highly exothermic and the hydrogen that is generated can react with oxygen to increase further the heat that is generated.
- **Reactions with non-metals :** The alkali metals can be burnt in the atmospheres of the various halogens to form the corresponding halides. The reactions are highly exothermic, producing up to 235 kcal/mole for lithium fluoride.
- Alkali metals react with non metals in Groups 15 and 16 (Va and VIa) of the periodic table. Sulphides can be formed by the direct reaction of the alkali metals with elemental sulphur, furnishing a variety of sulphides.
- Alkali metals combine with phosphorous to form phosphides with the general formula M_3P.
- **Formation of alloys:** The high-pressure transition in potassium, rubidium and cesium that converts these *s*-type metals to more transition metal-like *d*-type metals yields atomic volumes that are similar to those of many transition metals at the same pressure. This permits alloys or compounds to be formed between these alkali metals and such transition metals as nickel or iron.
- Lithium and Cesium can co-exist in two separate liquid phases at temperatures of upto at least 1,100 °C (2,000 °F).

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- There is only one example of solid miscibility in alkali–alkaline-earth-metal binaries, the lithium-magnesium system, in which the two elements are very similar. Sodium forms compounds only with barium in the alkaline-earth-metal series.
- Several elements in Group 12 (IIb) of the periodic table (zinc, cadmium and mercury) react with the alkali metals to form compounds. Mercury forms at least six compounds, commonly termed amalgams, with each of the five alkali metals, and with the exception of the amalgam with lithium, the highest melting point compound in each series has the formula MHg_2. Lithium and sodium also form compounds with cadmium and zinc.

Formation of complexes

- The synthesis of crown ethers by American chemist Charles J. Pedersen in 1967 provided size-selective cyclic molecules. Common crown ethers are 12-crown-4, 15-crown-5 and 18-crown-6. These molecules are selective for Li^+, Na^+, and K^+, respectively.

Difference in the chemistry of lithium and other alkali metals: Of all the alkali metals, lithium and magnesium have a diagonal relationship due to their similar atomic radii so that they show some similarities. For example:

- Lithium forms a stable nitride, a property common among all the alkaline earth metals but unique among the alkali metals.
- Lithium and magnesium form organometallic compounds with significant covalent character (e.g. LiMe and $MgMe_2$).
- Lithium fluoride is the only alkali metal halide that is poorly soluble in water.
- Lithium hydroxide is the only alkali metal hydroxide that is not deliquescent. This allows salts like lithium chloride and lithium bromide to be used in dehumidifiers and air-conditioners.
- Lithium forms a relatively stable hydride, whereas the other alkali metals form hydrides that are more reactive.
- Lithium forms a carbide (Li_2C_2) similar to that of calcium. The other alkali metals do not form stable carbides.

Applications of alkali metals :

- **Lithium and uses** :Lithium is often used in batteries, and lithium oxide can help process silica. Lithium stearate is a thickener and can be used for making lubricating greases. Lithium chloride is used as a brazing alloy for aluminium parts.
- **Sodium and uses**: Sodium compounds have many applications being sodium chloride used as table salt, sodium carbonate as washing powder($Na_2CO_3.10H_2O$), sodium hydrogen carbonate ($NaHCO_3$) as baking powder, Caustic soda (NaOH) and sodium salts of fatty acids as soap. Pure sodium metal also has many applications including use in sodium-vapour lamps. Being a strong reducing agent, it is often used to reduce metals, such as titanium and zirconium from

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their chlorides. Furthermore, it is very useful as a heat-exchange liquid in fast breeder nuclear reactors due to its low melting point, viscosity and cross-section towards neutron absorption.

- **Potassium and uses :** Potassium compounds are often used as fertilizers . Potassium being an important element for plant nutrition. Potassium hydroxide is a very strong base, and is used for controling the pH of various substances. Potassium nitrate and potassium permanganate are often used as powerful oxidising agents. Potassium superoxide is used in breathing masks, as it reacts with carbon dioxide to give potassium carbonate and oxygen gas.
- **Rubidium and cesium uses :** These are often used in atomic clocks. Cesium atomic clocks are extraordinarily accurate. For that reason, caesium atoms are used as the definition of the second. Rubidium ions are often used in purple fireworks, and caesium is often used in drilling fluids in the petroleum industry.

  Rubidium has been used as a component of photocells, to remove traces of oxygen from vacum tubes and to make special types of glass.
- **Francium** has no commercial applications but because of its relatively simple atomic structure and radioactive nature among other things, it has been used in spectroscopy experiments.
- **Preparation of potassium dichromate ($K_2Cr_2O_7$):** It is prepared from chromite ore $FeCr_2O_4$. The chromite ore is fused with sodium or potassium carbonate in free access of air.

  $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \longrightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$
- The yellow solution of sodium chromate is filtered and acidified with sulphuric acid to give a solution from which orange sodium dichromate, $Na_2Cr_2O_7\ 2H_2O$ can be crystallized.

  $2Na_2CrO_4 + 2H^+ \longrightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$
- Sodium dichromate is more soluble than potassium dichromate. Hence, sodium dichromate when fused with KCl forms orange crystals of potassium dichromate.

  $Na_2Cr_2O_7 + 2KCl \longrightarrow K_2Cr_2O_7 + 2NaCl$
- The chromates and dichromates are inter-convertible.

  $2CrO_4^{2-} + 2H^+ \longrightarrow Cr_2O_7^{2-} + H_2O$

  $Cr_2O_7^{2-} + 2OH^- \longrightarrow 2CrO_4^{2-} + H_2O$
- The dichromate ion and chromate ion exist in equilibrium with each other at a pH of 4. Yellow chromate changes into orange dichromate in acid medium and dichromate changes into chromate in basic medium.

Properties of Potassium dichromate ($K_2Cr_2O_7$):

- **Action of heat:** Potassium dichromate decomposes on heating to form potassium chromate, chromic oxide and oxygen.

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$4K_2Cr_2O_7 \longrightarrow 4K_2CrO_4 + 2CrO_3 + 3O_2$

- **Oxidizing properties :** Potassium dichromate is a powerful oxidizing-agent in acidic medium.

$Cr_2O_7^{2-} + 14H^+ + 6 \text{ electron} \longrightarrow 2Cr^{3+} + 7H_2O$

A few examples for this oxidizing character in acidic medium are

- It oxidizes iodides to iodine.

$Cr_2O7^{2-} + 14H^+ + 6I^- \longrightarrow 2Cr^{3+} + 7H_2O + 3I_2$

- It oxidizes ferrous salts to ferric salts.

$Cr_2O_7^{2-} + 14H^+ + 6\ Fe_2+ \longrightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$

- It oxidizes stannous salts to stannic salts.

$Cr_2O_7^{2-} + 14H^+ + 3Sn^{2+} \longrightarrow 2Cr^{3+} + 7H_2O + 3Sn^{4+}$

- It oxidizes H_2S to sulphur

$Cr_2O_7^{2-} + 8H^+ + 3H_2S \longrightarrow 2Cr^{3+} + 7H_2O + 3S$

- **Potassium Permanganate as oxidizing agent:** It works most efficiently in acidic solution, because it is reduced to the greatest extent in this medium, from oxidation state + VII in MnO4" to Mn2+

$$8H^+ + MnO_4 + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

- Therefore, the number of electrons transferred from oxidized species per mole $KMnO_4$ (5 electrons) is the largest, and the least amount of $KMnO_4$ is needed for the reaction with a certain amount of alcohol. This makes oxidation in acidic medium the best choice for economic reasons.
- The oxidation in neutral medium is less efficient, as manganese(VII) is only reduced to manganese (IV), yielding insoluble MnO_2 as a by product which needs to be removed from the reaction mixture during the purification of the desired product (carboxylic acid).

$$2H_2O + MnO_4^- + 3e^- \rightarrow MnO_2\downarrow + 4OH^-$$

- Oxidation in strongly alkaline medium is least efficient in terms of transferred electrons per mole permanganate, as the latter is only reduced to manganate (VI).

$$MnO_4^- + e^- \rightarrow MnO_4^{2-}$$

- However, when the reaction is done under these conditions, a higher reaction speed and selectivity can be achieved, presumably because the alcohol will react more readily with MnO_4–MnO_X when deprotonated. Nevertheless, oxidation in acidic medium can be preferred for the reasons stated above and substrates which are sensitive to strong bases.

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Chapter 10

ALKALINE EARTH METALS AND THEIR PROPERTIES

Position of alkaline earth metals in periodic table, their physical properties, their occurrence in nature, their chemical properties, solubility of their different salts down the group, uses of different alkaline earth metals.

➤ **Alkaline earth metals :** These are the elements present in the second column (column 2A) of the periodic table. This group includes beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra). Alkaline earth metals have only two electrons in their outermost electron layer. These elements get the name 'alkaline' because of the basic nature of the compounds, they form when bonded with oxygen.

Physical and atomic properties of the alkaline earth metals

Alkaline earth metal	Standard atomic weight (u)	Melting point (K)	Boiling point (K)	Density (g/cm^2)	Ist ionization energy ($kJ.mol^{-1}$)	Covalent radius (pm)	Flame Colour
Beryllium	9.012182	1560	2742	1.85	899.5	105	White
Magnesium	24.3050	923	1263	1.738	737.7	150	Brilliant-white
Calcium	40.078	1115	1757	1.54	589.8	180	Brick-red
Strontium	87.62	1050	1655	2.64	549.5	200	Crimson
Barium	137.327	1000	2170	3.594	502.9	215	Apple-green
Radium	[226]	973	2010	5.5	509.3	221	Crimson red

➤ **Occurrence of alkaline earth metals :** Beryllium occurs in the earth's crust at a concentration of two to six parts per million (ppm),much of which is in soils, where it has a concentration of six ppm. Beryllium is one of the rarest elements in sea-water, even rarer than elements such as scandium, with a concentration of 0.2 part per trillion. However, in fresh-water, beryllium is somewhat more common, with a concentration of 0.1 part per billion.

➤ Magnesium and calcium are very common in the earth's crust, with calcium the fifth-most-abundant element, and magnesium the eighth. None of the alkaline earth metals are found in their elemental state, but magnesium and calcium are found in many rocks and minerals:

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- Magnesium in carnallite, magnesite and dolomite.
- Calcium in chalk, limestone, gypsum and anhydrite.
- Strontium is the fifteenth-most-abundant element in the earth's crust. Most of it is found in the minerals : celestite and strontianite.
- Barium is slightly less common, much of it in the mineral barite. The most important supplier of barium is China. It produces more than 50% of the world supply.
- Radium, being a decay product of uranium, is found in all uranium-bearing ores. Due to its relatively short half-life, radium from the earth's early history has decayed, and presentday samples have all come from the much slower decay of uranium.

Chemical reactions of alkaline earth metals :

- **Reactions with Hydrogen :** All the alkaline earth metals react with hydrogen to create metallic hydrides.

$$Ca(s) + H_2(g) \rightarrow CaH_2(s)$$

- **Reactions with Oxygen :** Alkaine earth metals have an oxidation state of +2. The alkaline earth metals react with oxygen to produce metal oxides. An oxide is a compound containing oxygen in a -2 oxidation state. Except beryllium which form dioxide, all other alkaline earth metals react with oxygen to form their respective oxides.

$$Sr(s) + O_2(g) \rightarrow SrO_2(s)$$

- **Reactions with Nitrogen :** These reactions cannot occur in ordinary condition, extremely high temperatures are required. A theoretical reaction of an alkaline earth metal with nitrogen would proceed in the following manner:

$$3Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$$

- **Reactions with Halogens :** Alkaline earth metals react with halogens to form metal halides. A halide is a compound containing an ionic halogen. A reaction of this type between magnesium and chlorine is given below :

$$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$

- **Reactions with Water :** Beryllium does not react with water; however, magnesium, calcium, strontium and barium do react to form metal hydroxides and hydrogen gas.

$$Ba(s) + 2H_2O(l) \rightarrow Ba(OH)_2(aq) + H_2(g)$$

- **Reaction with acids :** Some sources say that beryllium does not react with nitric acid because of the presence of oxide layer on its surface. The rest of the Group 2 metals produce hydrogen gas from very dilute nitric acid, but this gas is contaminated with nitrogen oxides. Colourless solutions of the metal nitrates are also formed. Taking magnesium as an example, if the solution is very dilute:

$$Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$$

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- At moderate concentrations (even with very dilute acid, this occurs to some extent): $3Mg + 8HNO_3 \rightarrow 3Mg(NO_3)_2 + 2NO + 4H_2O$
  and with concentrated acid: $Mg + 4HNO_3 \rightarrow Mg(NO_3)_2 + 2NO_2 + 2H_2O$

Solubility of salts of alkaline earth metals:

Solubility of the hydroxides :

- The solubility of hydroxides increases down the group.
- This is a trend which holds for the whole group as magnesium hydroxide (Milk of magnesia, used as an antacid) appears to be insoluble in water. However, if it is shaken in water, it becomes sparingly soluble. Calcium hydroxide solution referred to as "lime water" is soluble but barium hydroxide is the most soluble.
- **Solubility of sulphates :** The solubility of sulphates decreases down the group, therefore, reaction between magnesium and dilute sulphuric acid produces hydrogen gas and a colourless solution of magnesium sulphate, it being soluble in water. But barium sulphate exists as a white precipitate in solution than as a solution.
- **Solubility of the carbonates :** The solubility of carbonates decreases down the group.
- All the Group 2 carbonates are very sparingly soluble. Magnesium carbonate, for example, has a solubility of about 0.02 g per 100 g of water at room temperature.
- **Thermal stability :** Carbonates and nitrates of Group 2 elements become more thermally stable down the group. The larger compounds further down require more heat than the lighter compounds in order to decompose.

Applications of alkaline earth metals :

- **Beryllium and uses :** It is used mostly for military application but there are other uses of beryllium, as well. In electronics, beryllium is used as a p-type dopant in some semiconductors and beryllium oxide is used as a high-strength electrical insulator and heat conductor. Due to its light weight and other properties, it is also used in mechanics when stiffness, light weight and dimensional stability are required at wide temperature ranges. It is used in aircraft production in the nozzles of liquid-fuelled spacecrafts and mirrors in meteorological satellites. The famous Spitzer Space Telescope's optics are composed entirely of beryllium.
- **Magnesium and uses :** It has many different uses particularly in industry, where it has many structural advantages over other materials such as aluminium. Although this usage has fallen out of favour recently due to magnesium's flammability. Magnesium

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is also often alloyed with aluminium or zinc to form materials with more desirable properties than any pure metal. Magnesium has many other uses in industrial applications such as a role in the production of iron and steel, and the production of titanium.

- Biologically, magnesium is important to green plants being the only metallic constituent of chlorophyll.
- **Calcium and uses :** It has many uses such as a reducing agent in the separation of other metals from ore, such as uranium. It is also used in the production of the alloys of many metals such as aluminium and copper alloys, and is also used to deoxidize alloys as well. Calcium and its compounds also have a role in the making of cheese, mortars and cement. It is commonly used in the production of limewater by the slaking of quick lime.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Quick lime Slaked lime

- Quick lime is also used for treating acidic soils before plantation in agriculture.
- Slaked lime in a laboratory is widely used for testing the presence of carbon dioxide and sulphur dioxide. With CO_2 it temporarily forms white ppt in low concentration but with SO_2 it gives permanently formed white ppt.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

$$CaCO_3 + 2H_2O + CO_2 \rightarrow Ca(HCO_3)_2 + H_2O$$

$$Ca(OH)_2 + SO_2 \rightarrow CaSO_4 + H_2$$

- Gypsum is used in the production of Plaster of Paris. When heated at 100°C, it produces POP (Plaster of Paris).

$$CaSO_4.2H_2O \rightarrow CaSO_4\frac{1}{2}H_2O + 1\frac{1}{2}H_2O.$$

- **Strontium and barium uses :** They do not have so many applications as the lighter alkaline earth metals, but still have uses. Strontium carbonate is often used in the manufacturing of red fireworks, and pure strontium is used in the study of neurotransmitter release in neurons and strontium chloride ($SrCl_2$) is used for making toothpaste for sensitive teeth.
- Barium is used in vacuum tubes for removing gases, and barium sulphate has many uses in the petroleum industry.
- Due to its radioactivity and rare availability, radium no longer has many applications.

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Chapter 11

Carbon Family Elements And Their Properties

Position of carbon family members in periodic table, their physical properties, their chemical properties, allotropy and allotropic forms of carbon, uses of different members of carbon family.

CHEMISTRY

➤ **Members of carbon family :** The carbon family, Group 14 in the p-block, contains carbon (C), silicon (Si), germanium (Ge), tin (Sn), lead (Pb) and flerovium (Fl). Each of these elements has only two electrons in its outermost p orbital. Each has the electron configuration ns^2np^2. The Group 14 elements tend to adopt the oxidation states of +4 and, for the heavier elements, +2 is also possible due to the inert pair effect.

Physical and atomic properties of the elements of carbon family

Element	Symbol	Atomic number	Atomic Mass	Classification	Electron Configuration
Carbon	C	6	12.011	Non-metal	$[He]2s^22p^2$
Silicon	Si	14	28.0855	Metalloid	$[Ne]3s^23p^2$
Germanium	Ge	32	72.61	Metalloid	$[Ar]3d^{10}4s^24p^2$
Tin	Sn	50	118.710	Metal	$[Kr]4d^{10}5s^25p^2$
Lead	Pb	82	207.2	Metal	$[Xe]4f^{14}5d^{10}6s^26p^2$
Flerovium	Fl	114	287	Metal	$[Rn]5f^{14}6d^{10}7s^27p^2$

➤ Members of this group conform well to general periodic trends.

(1) The atomic radii increase down the group,

(2) Ionization energies decreases.

(3) Metallic properties increase down the group.

Carbon is a non-metal, silicon and germanium are metalloids, and tin and lead are poor metals (they conduct heat and electricity less effectively than other metals such as copper).

➤ Despite their adherence to periodic trends, the properties of the carbon family vary greatly. For example, carbon is a non-metal and behaves as such, whereas tin and lead behave entirely as metals. In their elemental solid states, the Group 14 metalloids, silicon and germanium, act as electrical semiconductors, although silicon is largely non-metallic, its electrical conductivity can be affected in various degrees by *doping* or adding of Group 13 or Group 15 elements in varying concentrations to the Group 14 solid matrix. These semiconductor properties have wide applications for circuitry components in the electronics industry, such as diodes, transistors and integrated circuit (IC) chips.

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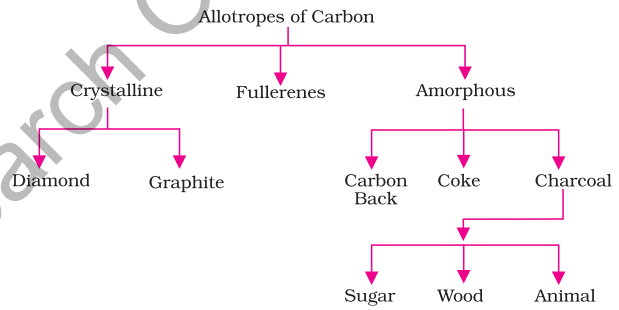
- **Carbon :** Carbon is the fourth most abundant element on the earth. It is of particular interest in organic chemistry, as it is the distinguishing feature of an organic compound. Carbon is also considered the "backbone" of biology, as all life forms on the earth are carbon-based. This is due to two important qualities of carbon: its small size and its unique electron configuration. The property of carbon that allows it to form strong covalent bonds with itself and other elements like hydrogen to form long straight chain, branched chain or ring chain compounds is called catenation. Therefore, if the structure of a molecule of CO_2 and SiO_2 is compared , it is found that CO_2 has double bonds between carbon and oxygen atoms, whereas SiO_2 has single bonds. The CO_2 molecule exists freely in the gaseous phase. The SiO_2 molecule, by contrast, always exists within a network of covalent bonds.
- Carbon's electron configuration allows it to form very stable bonds with oxygen and hydrogen. These bonds store an enormous amount of energy. The formation (fixation) and breakage (combustion) of these bonds in the carbon cycle facilitate earthly life.
- **Carbon fixation :** In photosynthesis, plants use energy from the Sun and chlorophyll molecules to turn gaseous carbon dioxide from the atmosphere into simple carbohydrates, *i.e.* glucose :

$$6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

- **Carbon combustion:** In aerobic respiration, plants and animals break carbohydrates down into carbon dioxide and water and use the energy released to fuel biological activities like growth, movement, etc. In addition, the combustion of carbohydrates found in fossil fuels provides energy needed for modern activities.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$



- **Allotropes of carbon :** Next to sulphur, carbon is the element with the most allotropes. Carbon has three main solid state allotropes: graphite, diamond and fullerenes (buckminster fullerene) is also known as a "buckyball"). These allotropes differ greatly in structure but are widely used in modern production.
- **Graphite :** It has lubricating properties that makes it extremely suitable for use in pencils. It is made up of the planes of six-

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membered rings that can easily slide past one another, graphite slides easily and is hence used in combination with clay to form pencil "lead." filling tyres, etc. Graphite is also used in a fibrous form for various plastics.

- Carbon has very high melting and boiling points. Graphite is the most thermodynamically stable allotrope of carbon under ordinary conditions.
- **Diamond :** Diamond, is the more stable allotrope at extreme pressures (10^5 atm and above), each carbon atom is bonded to four others in a tetrahedral arrangement, resulting in the hardest naturally-occurring substance known. This hardness, combined with a good ability to dissipate heat, makes a diamond and diamond film excellent materials in drill bits and other machine parts. However, the highest-quality natural diamonds are used mainly for jewellery, whereas a lower-grade diamond or even synthetic diamond is used for industrial purposes. Diamond has the highest value of retractive index of all naturally found substances.
- Synthetic diamonds also called American diamonds are produced by heating graphite at temperature of 2500°C or above in the absence of air.
- **Fullerenes :** These allotropes, named after R. Buckminster Fuller are a series of carbon allotropes in which carbon rings form more complex forms, including soccerball-like molecules (C_{60}) and nano-tubes resembling cylinders made of chicken wire. Graphene, a single carbon sheet with intriguing electronic properties, is the basis for these allotropes. Fullerenes occur when a certain percentage of hexagonal rings are assembled to form pentagonal rings, causing the sheet to contort into a roughly spherical "Buckyball". A carbon nanotube is simply graphene bent into a cylinder. Some of these allotropes are formed on the decomposition of graphite.
- **Amorphous forms of carbon :** There is a wide range of amorphous forms of carbon such as coke , carbon black , charcoal, etc. Coke is produced by the dry distillation of coal. It is widely used as a fuel and a reducing agent in metallurgical operations such as in the reduction of oxides of zinc and iron.

$$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$$
$$ZnO + C \rightarrow Zn + CO$$

- Of all these forms of allotropes of carbon, sugar charcoal is considered to be the purest form of carbon. It is produced by dehydrating cane sugar with warm concentrated sulphuric acid.

$$C_{12}H_{22}O_{11} \xrightarrow{\text{Warm Conc. } H_2SO_4} 12C + 11H_2O$$

- There is nearly an innumerable amount of different carbon compounds, but several inorganic compounds are particularly important too.

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Carbonate minerals	
Formula	**Name of the mineral**
Na_2CO_3	Soda ash or Natrite
$CaCO_3$	Lime stone or Calcite or Aragonite or Chalk
$MgCO_3$	Magnesite
$CaCO_3.MgCO_3$	Dolomite
$SrCO_3$	Strontianite
$BaCO_3$	Witherite
$PbCO_3$	Cerrusite
$FeCO_3$	Siderite
$CuCO_3.Cu(OH)_2$	Malachite
$2[CuCO_3].Cu(OH)_2$	Azurite
$ZnCO_3$	Smithsonite (in the old literature it is known as calamine)
$CdCO_3$	Otavite

- **Carbides :** These are compounds of carbon and metals, used in many industrial processes, often to stabilize other metal structures; calcium carbide is used for fabricating industrial chemical compounds, for example, carbon disulphide and carbon tetrachloride are powerful solvents, (although since its classification as a carcinogen, CCl_4 use has declined).
- **Cyanides :** They behaves similarly to halide ions, forming both a salt and an acid. Hydrocyanic acid (HCN) is a weak acid with an extremely low boiling point (room temperature, in fact), and is used in plastic production. A cyanide dimer is called a cyanogen, and it is used in organic synthesis, as fumigants and a rocket propellant.

Chemical Properties of Carbon

- Carbon is a non-metal and it forms a lot of covalent compounds.
- **Formation of Hydrides :** Carbon combines with hydrogen to form compounds such as methane CH_4. These hydrides formed are covalent in nature.
- **Oxides :** There are two oxides of carbon. Carbon monoxide and carbon dioxide which is the major end-product of combustion and aerobic respiration. CO_2 is one of the Greenhouse gases. Therefore, its increasing concentration contributes to the increasing adverse effects of global warming: The other oxide, C_2O_2 also exists.
- Carbon monoxide (CO) is used for synthesizing other carbon compounds, reducing metal compounds to usable products, and in combination with other gases for fuel. Carbon monoxide is

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considered toxic because haemoglobin in red blood cells has 250 times more affinity to it than oxygen. Hence, in its presence body cells suffer oxygen starvation and die.

- **Reaction with halides :** Carbon reacts with all halides to form a tetrahalide - MX_4 . This halide is thermally very stable. Tetra halides of carbon are the only ones which are not hydrolyzed by water, due to the absence of 'd' orbital in carbon.

$$M + X_2 \rightarrow MX_4$$

- **Formation of acids :** Carbon forms both organic and inorganic acids. It forms carbonic acid, H_2CO_3, the inorganic acid. There is a whole range of acid, with a chemical formula -COOH formed by carbon. These are studied separately in the name of carboxylic acid under organic chemistry.
- **Reaction with alkalies :** Carbon does not react with alkalies, though all the other elements in its group are attacked by alkalies.
- Carbon forms a lot of compounds. Some of them, with their methods of preparation, are as follows:
- Percarbonic acids and percarbonates: Carbon forms two percarbonic acids which are

(i) **Permonocarbonic acid :** These are the salts H_2CO_4. The examples of such salts are Na_2CO_4, K_2CO_4, etc.
Na_2CO_4 is prepared from the reaction between Na_2O_2 and phosgene, $COCl_2$.

$$2Na_2O_2 + COCl_2 \rightarrow Na_2CO_4 + 2NaCl + 1/2O_2$$

(ii) **Perdicarbonates :** Per-acids are derivatives of hydrogen peroxide These are derived from $H_2C_2O_6$. These are best represented by potassium and sodium salts whose formula are $K_2C_2O_6$ and $Na_2C_2O_6$ respectively $Na_2C_2O_6$ is prepared by passing F_2 in a concentrated solution of Na_2CO_3 at -13 °C to -16°C.

$$2Na_2CO_3 + F_2 \rightarrow Na_2C_2O_6 + 2NaF$$

- **Carbonyl chloride or phosgene :** This compound was discovered by John Davy in 1811. It has a chemical formula of $COCl_2$. It is prepared by the direct combination of equal volumes of CO and Cl_2 in the presence of bright sunlight.

$$CO + Cl_2 \rightarrow COCl_2$$

- Phosgene is a colourless gas with a penetrating and suffocating odour of rotten fish and is highly poisonous and life-threatening to people involved in fire-fighting, particularly of electrical fires using carbon tetrachloride.
- **Carbon disulphide :** This compound CS_2 is manufactured by passing sulphur vapour over hot charcoal or coke.
- **Silicon :** It is the second most common element in the earth's crust (after oxygen) and is the backbone of the mineral world. It is classified as neither a metal nor a non-metal, but a metalloid. Silicon is inert, primarily reacting with halogens. Plants depend on silicates (such as $[SiO_4]^{4-}$) to hold nutrients in the soil, where their roots

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can absorb them. SIlicon (primarily in the silica, SiO_2, molecule) has been used for millennia in the creation of ceramics and glass. In more recent history, the name "Silicon Valley" attests to the element's importance in the computing industry— if carbon is the backbone of human intelligence, silicon is the backbone of artificial intelligence. Silicon is found in beach sand, and is a major component of concrete and brick.

- Pure silicon dioxide is found in Nature in crystalline form as quartz. Impure silicon dioxide is found in the form of sand, flint and oxygen (gem stone) silicates of aluminium, magnesium, iron and other metals are found in rocks and soil, etc. SO_2 is the most prevalent compound found in the earth's crust.
- **Preparation of Silicon :** Silicon can be prepared by :
- **Acheson Process :** In this process, a mixture of coke and sand (silica) is subject to intense heat, *i.e.* 3000 K in an electro-thermal furnace, where reaction takes place and silica is converted into silicon carbide which on decomposition gives silicon are and graphite.

$$SiO_2 + 2C \rightarrow SiC + CO$$
$$SiC \rightarrow Si + C$$

- **Heating Silica with Magnesium :** In this method, a mixture of silica (quartz) powdered and powdered magnesium are heated. Reaction takes place and magnesium oxide and silica are formed.

$$SiO_2 + 2\ Mg \rightarrow 2MgO + Si$$

- **Heating Silicon Tetra Chloride with Aluminium :** In this method, a mixture of silicon tetrachloride and aluminium is strongly heated. Reaction takes place and silicon is formed.

$$3SiCl_4 + 4Al \rightarrow 4AlCl_3 + 3Si$$

Chemical Properties of Silicon : Amorphous silicon is more reactive than crystalline silicon. At room temperature, silicon is meant to more of the chemical reagents behaviour. However, some of the chemical reactions are as under.

- **Reaction with Alkalis :** It reacts with strong basic solutions (alkalies) to form hydrogen gas.

$$Si + 2KOH + H_2O \rightarrow K_2SiO_3 + 2H_2.$$

- **Reaction with Air :** It burns in the air at 450K to form silicon oxide.

$$Si + O_2 \rightarrow SiO_2$$

- **Reaction with Chlorine :** It chemically combines with chlorine on heating to form silicon tetrachloride.

$$Si + 2Cl_2 \rightarrow SiCl_4$$

- **Reaction with Steam :** It reacts with steam to form silicon dioxide with the liberation of hydrogen gas.

$$Si + 2H_2O \rightarrow SiO_2 + 2H_2$$

- **Reaction with Metals :** It reacts with metals to form siliodes, e.g,

$$2Mg + Si \rightarrow Mg_2Si \text{ or } MgSi$$

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- **Reaction with Hydrochloric Acid :** It reacts with hydrochloric acid on heating to form hydrogen gas.

$$3HCl + Si \rightarrow SiHCl_3 + H_2$$

- **Compounds of Silicon :** Some of the important compounds of silicon include:
- Silicon dioxide (silica or commonly called sand), Silicon tetrachloride ($SiCl_4$), Sodium silicate (Na_2 Sio_3) and Asbestos ($CaMg_3$) $(SiO_3)_4$.
- **Germanium :** It is a rare element used in the manufacture of semi-conductor devices. The physical and chemical properties of germanium are very similar to those of silicon. Being a semi-metal, germanium's abundance in the earth's crust is approximately 1.6 ppm. Only a few minerals like argyrodite,briartite, germanite, and renierite contain appreciable amounts of germanium, Germanium is grey-white in colour and forms crystal structures.
- **Uses of germanium :** The major end uses for germanium in 2007, worldwide, were estimated to be: 35% for fibre-optics, 30% infrared optics, 15% polymerization catalysts and 15% electronics and solar electric applications. The remaining 5% went into such uses as phosphors, metallurgy and chemotherapy. The notable properties of germania (GeO_2) are its high index of refraction and its low optical dispersion. These make it, especially useful for wide-angle camera lenses, microscopy and the core part of optical fibres.
- **Solar panels are a major use of germanium :** Germanium is the substrate of the wafers for high-efficiency multi junction photovoltaic cells for space applications. High-brightness LEDs, used for automobile headlights and to backlight LCD screens, are important applications. Germanium dioxide is also used in catalysts for polymerization in the production of polyethylene terephthalate (PET).The high brilliance of this polyester is specially favoured for PET bottles. Due to the similarity between silica (SiO_2) and germanium dioxide (GeO_2), the silica stationary phase in some gas chromatography columns can be replaced by GeO_2.
- **Tin :** Tin is a soft, malleable metal with a low melting point. Tin has an atomic number 50 and it is a post-transition metal in group 14. of the periodic table. It has two solid-state allotropes at regular temperatures and pressures, denoted S*n* and S*n*. At higher temperatures (above 13°C), tin exists as white tin or S*n*-tin, and is often used in alloys. At lower temperatures, tin can transform into grey tin, (S*n*-tin) it loses its metallic properties and turns powdery. This causes the disintegration of items made from white tin alloys that have been exposed to the cold for long periods of time. The pipes in Europe's great pipe organs are a classic victim of this "tin pest". When a crystalline structure is broken, a "tin cry" is heard; this happens when a bar is bent. Grey tin is used for plating iron food cans prevent them from rusting. Tin is malleable, ductile and crystalline. Cassiterite (SnO_2) is the only commercially important source of tin, although small quantities of tin are recovered from complex sulphides such as stannite, cylindrite franckeite, canfieldite

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and teallite. It has 27 isotopes : 9 stable and 18 unstable. It is a superconductor at low temperatures. Tin reacts with bases, acid salts and strong acids. Tin chlorides are good reducing agents and often used to reduce iron ores. Tin fluoride is often the anticavity "fluoride" additive in toothpastes.

Physical Properties of Tin	
Colour	Silver-White
Malleability	Capable of being shaped or bent into extremely thin sheets (tin foil).Gives off a weird, screeching sound when bent.
Lustre	Has a shine or glow.
Ductility	Easily pulled or stretched into a thin wire
Conductivity	Good transmission of heat or electricity
Softness	Very soft (only slightly harder than lead)
Crystalline Structure	Tetragonal
Chemical Properties of Tin	
Oxidation	Not easily oxidized but oxidizes upon heating with concentrated HNO_3.
Reactivity with water	Stable in both cold and boiling water
Reactivity with acids	Does not react rapidly.
Toxicity	Relatively low toxicity but most compounds of tin are toxic (poisonous).
Corrosion	Resists corrosion because it is protected by an oxide film.
Alloys	Used extensively in alloys, e.g., bronze and pewter. It is 50% alloy with lead used for soldering.
Allotrope	Two allotropic forms of tin are known: grey tin and the more common white tin.
Compounds	Reacts with the halogens to form compounds $SnCl_4 + Sn \rightarrow 2\ SnCl_2$

➢ **Lead :** Lead (also known as plumbate) is similar to tin in respect that it is a soft, malleable metal with a low melting point. It was formerly used in water and sewage pipes, lending its Latin name (*plumbum*) to the terms "plumber" and "plumbing". Lead is toxic to humans, especially children. Even low levels of exposure can cause damage to the nervous system and can prevent proper production of haemoglobin (the molecule in red blood cells responsible for carrying oxygen through the body). Because of this, there has been concerted effort to reduce public exposure to lead, including an emphasis on using unleaded gasoline and unleaded paint. Lead is

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typically stable in an oxidation state of +2 or +4. Its oxides have many industrial uses as oxidizing agents, such as cathodes in lead acid storage cells.

Physical Properties of Lead	
Colour	Bluish-white
Malleability	Capable of being shaped or bent
Conductivity	Poor transmission of heat or electricity
Softness	Relatively soft
Tensile	It can be stretched without breaking
Lustre	A shine or glow
Crystalline structure	FCC crystalline structure

- Lead is a moderately active metal. It dissolves slowly in water and in most of the cold acids. It reacts more rapidly with hot acids. It does not react with oxygen in the air readily and does not burn.

Chemical properties of lead	
Reactivity with water	Dissolves slowly in water
Oxidation	Does not readily react with oxygen in the air
Inflammability	Does not burn
Reactivity with acids	Reacts quickly with hot acids but slowly to cold acids
Corrosion	Very resistant to corrosion but tarnishes upon exposure to air
Toxicity	Toxic

- **Flerovium :** Flerovium (Fl) is also known as Element 114. It was discovered in 1998 by scientists in Dubna. It is radioactive and very short-lived.

Group 14 - Element Facts					
	C	**Si**	**Ge**	**Sn**	**Pb**
Melting point (°C)	3500 (diamond)	1410	937.4©	231.88	327.502
Boiling point (°C)	4827	2355	2830	2260	1740
Density (g/cm^3)	3.51 (diamond)	2.33	5.323	7.28	11.343
Ionization energy	1086	787	762	709	716
Atomic radius (pm)	77	118	122	140	175
Ionic radius (pm)	260 (C^{4-})	—	—	118 (Sn^{2+})	119 (Pb^{2+})
Usual oxidation number	+3, -4	+4	+2, +4	+ 2, +4	+2, +3

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Chapter 12

Chalcogens, Members of Oxygen Family

Chalcogens, their position in periodic table, their isotopes and different allotropes, crystal structure of chalcogens, oxidation states of different chalcogens, their compounds with pictogens, halogens and involvement in the formation of some of organic compounds, their occurrence in nature, their importance in industry and to living organisms.

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- **Chalcogens :** These are the chemical elements in Group 16 of the periodic table. This group is also known as the oxygen family. It consists of the elements: oxygen (O), sulphur (S), selenium (Se), tellurium (Te) and the radioactive element polonium (Po). The chemically uncharacterized synthetic element livermorium (Lv) is predicted to be a chalcogen as well.

General properties of chalcogens : The trends in their general properties as listed in the table are :

- The metallic properties increase in the order of oxygen, sulphur, selenium, tellurium or polonium. Polonium is essentially a metal. It was discovered by Madame Curie, who named it after her native country Poland.
- Electronegativity, ionization energy (or ionization potential IP), and electron affinity decrease for the group as atomic weight increases.
- The atomic radii and melting point increase down the group.
- Oxygen differs from sulphur in both physical and chemical properties due to its small size. The differences between oxygen and sulphur are more than the differences between other members.
- Metallic character increases down the group, with tellurium classified as a metalloid and polonium as a metal.
- Lighter chalcogens are typically nontoxic & heavier are toxic in nature.

Element	Atomic number	Electronic configuration	Melting point	Boiling point	Density at STP (g/cm3)
Oxygen	8	2, 6	219	183	0.00143
Sulphur	16	2, 8, 6	120	445	2.07
Selenium	34	2, 8, 18, 6	221	685	4.3
Tellurium	52	2, 8, 18, 18, 6	450	988	6.24
Polonium	84	2, 8, 18, 32, 18, 6	254	962	9.2
Livermorium	116	2, 8, 18, 32, 32, 18, 6			

- **Oxygen family and isotopes :** Oxygen has three stable isotopes and 14 unstable ones. Sulphur has four stable isotopes, 20 radioactive ones and one isomer. Selenium has six observationally stable or nearly stable isotopes, 26 radioactive isotopes and 9 isomers. Tellurium has eight stable or nearly stable isotopes, 31 unstable ones and 17 isomers. Polonium has 42 isotopes; none of which are stable. It has an additional 28 isomers. In addition to the stable isotopes, some radioactive chalcogen isotopes occur in nature, either because they are decayed products, such as Po, because they are primordial, such as Se, because of cosmic rays spallation, or via nuclear fission of uranium. Livermorium isotopes 290 through 293 have been discovered. The most stable livermorium isotope is Lv, which has a half-life of 0.061 second.
- **Allotropes :** The four stable chalcogens at STP exist in their isotopic form. These are:
- **Oxygen :** The most common allotrope is diatomic oxygen, or O_2, a reactive paramagnetic molecule that is essential to aerobic organisms. It has a blue colour in its liquid state. Another allotrope is O_3 or ozone which is three oxygen atoms bonded together in bent formation. Ozone is considered as the chemical weed because on the earth at surface, it exists, as a blue toxic gas but high up in stratosphere it protects life by preventing the UV rays to enter the earth's atmosphere. There is also an allotrope called tetraoxygen or O_4 and six allotropes of solid oxygen including "red oxygen", which has the formula O_8.
- Allotropes of oxygen are dioxygen, ozone, atomic oxygen (free radical), singret oxygen (either of two metastable states of oxygen), Tetraoxygen, solid oxygen.
- **Sulphur :** It has over 20 known allotropes, which is more than any other element except carbon. The most common allotropes are in the form of eight-atom rings, but other molecular allotropes that contain as few as two atoms or as many as 20 are known. Other notable sulphur allotropes include rhombic sulphur and monoclinic sulphur. Rhombic sulphur is the more stable of the two allotropes. Monoclinic sulphur takes the form of long needles and is formed when liquid sulphur is cooled to slightly below its melting point. The atoms in liquid sulphur are generally in the form of long chains, but above 190°Celsius, the chains begin to break down. If liquid sulphur above 190°Celsius is frozen very rapidly, the resulting sulphur is amorphous or "plastic" sulphur. Gaseous sulphur is a mixture of S_2 and S_8 atom rings.
- **Selenium :** It has at least five known allotropes. The grey allotrope, commonly referred to as the "metallic" allotrope, despite not being a metal, is stable and has a hexagonal crystal structure. The grey

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allotrope of selenium is soft and brittle. The four other allotropes of selenium are metastable. These include two monoclinic red allotropes and two amorphous allotropes, one of which is red and the other is black. The red allotrope converts to the black allotrope in the presence of heat. The grey allotrope of selenium is made from spirals on selenium atoms, while one of the red allotropes is made of stacks of selenium rings (Se_8).

- **Tellurium** is not known to have any allotropes, although its typical form is hexagonal.
- **Polonium :** It has two allotropes, which are known as α-polonium and β-polonium. α-polonium has a cubic crystal structure. It converts to the rhombohedral β-polonium at 36°C.
- **Crystal structure of chalcogens :** The chalcogens have varying crystal structures. Oxygen's crystal structure is monoclinic, sulphur's is orthorhombic, selenium and tellurium have the hexagonal crystal structure, while polonium has a cubic crystal structure.
- **Chalcogens and oxidation states :** Oxygen, sulphur and selenium are non-metals, and tellurium is a metalloid, It is not certain whether polonium is a metal or a metalloid. Some sources refer to polonium as a metalloid, although it has some metallic properties.
- Although Oxygen is a chalcogen yet its chemical properties differ from those of other chalcogens because the heavier chalcogens have vacant d-orbitals. Oxygen's electronegativity is also much higher than that of the other chalcogens. This makes oxygen's electric polarizability several times lower than that of the other chalcogens.
- **Chalcogens and oxidation number :** The oxidation number of the most common chalcogen compounds with positive metals is –2. However the tendency for chalcogens to form compounds in the –2 state decreases down the group. Other oxidation numbers, such as –1 in pyrite and peroxide, do occur. The highest formal oxidation number is +6.This oxidation number is found in sulphates, selenates, tellurates, polonates and their corresponding acids, such as sulphuric acid.
- **Oxygen oxidation state :** It is –2, and the oxidation state –1 is also relatively common. It is the most electronegative element except for fluorine, and forms compounds with almost all of the chemical elements, including some of the noble gases. It commonly bonds with many metals and metalloids to form oxides, including iron oxide, titanium oxide and silicon oxide. With hydrogen it form water and hydrogen peroxide. Oxygen ions often come in the form of oxide ions [O^{2-}], peroxide ions $\left[O_2^{-2}\right]$ and hydroxide ions [OH^-].

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- **Sulphur's oxidation states :** These are –2, +2, +4, and +6. Its chemistry is similar to oxygen's, in many ways except that sulphur-sulphur double bonds are far weaker than oxygen-oxygen double bonds, but sulphur-sulphur single bonds are stronger than oxygen-oxygen single bonds. Sulphur ions generally come in the form of sulphides [S^{2-}], sulphites $\left[SO_2^{-3}\right]$, sulphates $\left[SO_2^{-4}\right]$, and thiosulphates $\left[S_2O_2^{-3}\right]$.
- **Selenium's oxidation states** : These are –2, +4, and +6. It bonds with oxygen. Selenium ions usually come in the form of selenides (Se^{2-}) and selenates $\left[SeO_2^{-4}\right]$.
- **Tellurium's oxidation states :** These are –2, +2, +4, and +6. It forms the oxides tellurium monoxide, tellurium dioxide and tellurium trioxide. Tellurium ions often come in the form of tellurates $\left[TeO_2^{+4}\right]$ and for polonium's oxidation states are +2 and +4.
- There are many acids containing chalcogens, including sulphuric acid, sulphurous acid, selenic acid and telluric acid. All hydrogen chalcogenides are toxic except for water. Molecules containing metal bonded to chalcogens are common as minerals. For example, pyrite (FeS_2) is an iron ore Zinc blende (ZnS) and Copper pyrites ($CuFeS_2$). The rare mineral calaverite is the ditelluride (Au, Ag)Te_2.
- **Chalcogens and halogens :** Out of the compounds consisting purely of chalcogens and halogens, there are a total of 13 chalcogen fluorides, nine chalcogen chlorides, eight chalcogen bromides and six chalcogen iodides that are known.The heavier chalcogen halides often have significant molecular interactions. Sulphur fluorides with low valences are fairly unstable. However, sulphur fluorides with high valences, such as sulphur hexafluoride, are stable and well-known. Sulphur tetrafluoride [F_4S] is also a well-known sulphur fluoride. Certain selenium fluorides, such as selenium difluoride, have been produced in small amounts. The crystal structures of both selenium tetrafluoride and tellurium tetrafluoride are known. The mixed chalcogen-halogen compounds include SeSX, with X being chlorine or bromine. Diselenium diiodide, [Se_2I_2] however, occurs in equilibrium with selenium atoms and iodine molecules. Some tellurium halides with low valences, such as Te_2Cl_2 and Te_2Br_2, form polymers when in the solid state. These tellurium halides are synthesized by the reduction of pure tellurium with super hydride and reacting the resulting product with tellurium tetrahalides. Tellurium also forms iodides with even fewer iodine atoms than diiodides. These include TeI and Te_2I. These compounds have extended structures in the solid state.
- **Chalcogens and organic compounds :** Alcohols, phenols and other similar compounds contain oxygen. However, in thiols, selenols and tellurols: sulphur, selenium and tellurium replace oxygen.

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Thiols are better known than selenols or tellurols. Thiols are the most stable chalcogenols and tellurols are the least stable, being unstable in heat or light. Other organic chalcogen compounds include thioethers, selenoethers and telluroethers. Some of these, such as dimethyl sulphide, diethyl sulphide, and dipropyl sulphide are commercially available. Selenoethers are in the form of R_2Se or RSeR.

- **Chalcogens and metals :** Elemental chalcogens react with certain lanthanide compounds to form lanthanide clusters rich in chalcogens. Uranium(IV) chalcogenol compounds also exist. There are also transition metallic chalcogenols which have potential to serve as catalysts and stabilize nanoparticles.
- There is a very large number of metal chalcogenides with recently discovered group of compounds Rb_2Te. There are also compounds in which there are alkali metals and transition metals such as the fourth period transition metals except for copper and zinc. Highly metal-rich metal chalcogenides, such as Lu_7Te and Lu_8Te, have domains of the metal's crystal lattice containing chalcogen atoms.
- **Chalcogens and pnictogens :** Pnictogens are the members of the nitrogen family. Among all chalogens oxygen and sulphur form the number of compounds with nitrogen and phosphorus including their oxides and sulphides of phosphorous like phosphorous sulphide, "strike anywhere" matches compound. Chalcogens also bond with other pnictogens, such as arsenic, antimony and bismuth. Heavier chalcogen pnictides tend to form ribbon-like polymers instead of individual molecules. Chemical formulas of these compounds include Bi_2S_3 and Sb_2Se_3.
- **Chalcogens and other compounds :** All of the chalcogens form hydrides. In some cases, this occurs with chalcogens bond with two hydrogen atoms. However, tellurium hydride and polonium hydride are both volatile and highly labile. Also, oxygen can bond to hydrogen in a 1:1 ratio as in hydrogen peroxide, but this compound is unstable.
- Chalcogen compounds form a number of interchalcogens. For instance, sulphur forms the toxic sulphur dioxide and sulphur trioxide. Tellurium also forms oxides. There are some chalcogen sulphides as well. These include selenium sulphide, an ingredient in some shampoos.

Occurrence of chalcogens in nature:

- Oxygen makes up 21% of the atmosphere by weight, 89% of water by weight, 46% of the earth's crust by weight and 65% of the human body. It also occurs in many minerals, being found in all oxide minerals and hydroxide minerals, and in numerous

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other mineral groups. It is the third-most abundant element in the universe, making up 1% of the universe by weight.

- Sulphur makes up 0.035% of the earth's crust by weight, making it the 17th most abundant element that makes up 0.25% of the human body. It is a major component of soil. It makes up 870 parts per million of sea water and about 1 part per billion of the atmosphere. It is found in elemental form or in the form of sulphide minerals, sulphate minerals, or sulpho salt minerals. It is the tenth most abundant element in the universe, making up 500 parts per million of the universe by weight.
- Selenium makes up 0.05 parts per million of the earth's crust by weight. It is the 67th most abundant element in the earth's crust. It makes up on average 5 parts per million of the soil. Sea water contains around 200 parts per trillion of it. The atmosphere contains 1 nanogram of selenium per cubic metre. There are mineral groups known as selenates and selenites containing selenium.
- There are only 5 parts per billion of tellurium in the earth's crust and 15 parts per billion in sea water. It is one of the eight or nine least abundant elements in the earth's crust. There are a few dozen tellurate minerals and telluride minerals, and tellurium occurs in some minerals with gold, such as sylvanite and calaverite. Tellurium makes up 9 parts per billion of the universe by weight.
- Polonium only occurs in trace amounts on the earth, via radioactive decay of uranium and thorium. It is present in uranium ores in concentrations of 100 micrograms per metric ton. Very minute amounts of polonium exist in the soil and thus in most food, and so in the human body. The earth's crust contains less than 1 part per billion of polonium, making it one of the ten rarest metals on the earth.
- Livermorium is always produced artificially in particle accelerators.
- **Manufacture of sulphuric acid :** Today world-wide sulphuric acid is produced by catalytic oxidation of SO_2 into SO_3 in controlled conditions. The steps involved include :
- **Preparation of SO_2:** SO_2 is obtained by burning sulphur or by heating iron pyrite (FeS_2) in a pyrite burner.

$$S + O_2 \rightarrow SO_2$$

$$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$$

Oxidation of SO_2 to produce SO_3 in contact tower.Oxidation of SO_2 is carried out in contact tower where V_2O_5 as catalyst is filled in different pipes. SO_2 here reacts with air (O_2) to produce SO_3. Under above conditions 98% SO_2 is converted into SO_3.

$$2SO_2 + O_2 \rightarrow 2SO_3 + 45 \text{ Kcal.}$$

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To obtain high yield there has to be : Excess of O_2. - Optimum temperature for this process is 450°C to 500°C. Since volumes of reactants are greater than the product (3:2), therefore, a high pressure is favourable. Optimum pressure is about 1.5 to 1.7 atmosphere. At low temperature, rate of reaction decreases. To increase the rate of reaction, a catalyst vanadium pentaoxide (V_2O_5) is used. SO_3 is soluble in water, hence, can directly be used for the production of sulphuric acid but it is not observed, the reaction being highly exothermic. First, SO_3 is dissolved in sulphuric acid itself to produces oleum (Pyrosulphuric acid) which, later on its hydrolysis produces sulphuric acid of the desired concentration.

$$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7 \text{ (OLEUM)}$$
$$H_2SO_7 + H_2O \rightarrow H_2SO_4 + H_2SO_4.$$

Uses of chalcogens :

- Steel making is the most important use of oxygen, 55% of all oxygen produced goes to this application. The chemical industry also uses large amounts of oxygen 25% of all oxygen produced while the remaining 20% of oxygen produced is mostly split between medical use, water treatment, rocket fuel in liquid form in cryogenic engines and metal cutting.
- Most sulphur produced is transformed into sulphur dioxide, to manufacture sulphuric acid, a very common industrial chemical 60% of which is used in the production of phosphoric acid. (H_3PO_4).
- Phosphoric acid is produced from fluorapatite, known as phosphate rock, $3Ca_3(PO_4)_2.CaF_2$, by the addition of concentrated (93%) sulphuric acid in a series of well-stirred reactors. This results in phosphoric acid and calcium sulphate (gypsum) plus other insoluble impurities.
- Fluoride, as H_2SiF_6, is removed at a further stage by evaporation.
- Although the reaction takes place in stages involving calcium dihydrogenphosphate, yet the overall reaction can be represented as:

$$Ca(PO_4)_2(S) + 3H_2SO_4(l) \rightarrow 2H_3PO_4(l) + 3CaSO_4(S)$$

- Sulphur is a key ingredient of gunpowder and antibiotics called sulpha-drugs.
- Sulphur is mixed into rubber and heated for vulcanizing it.
- Sulphur is used in some types of concrete and fireworks.
- Around 40% of all selenium produced goes to glass making. 30% of all selenium produced goes to metallurgy, including manganese production. 15% of all selenium produced goes to agriculture.
- Electronics such as photovoltaic materials claim 10% and

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pigments account for 5% of all selenium produced. Historically, machines such as photocopiers and light meters used one-third of all selenium.

- Tellurium suboxide, a mixture of tellurium and tellurium dioxide, is used in the rewritable data layer of some CD-RW discs and DVD-RW discs.
- Bismuth telluride is also used in many microelectronics devices such as photoreceptors.
- It is used as a high-efficiency material in solar panels.
- Some of polonium's applications relate to the element's radioactivity. For instance, polonium is used as an alpha-particle generator for research. Polonium alloyed with beryllium provides an efficient neutron source. Polonium is also used in nuclear batteries. Most polonium is used in anti-static devices. Livermorium does not have any uses whatsoever due to its extreme rarity and short half-life.
- **Chalcogens and living organisms :** Oxygen is needed by almost all organisms for the purpose of generating ATP. It is also a key component of most other biological compounds, such as water, amino acids and DNA. Human blood contains a large amount of oxygen. Human bones contain 28% oxygen. Human tissue contains 16% oxygen. A typical 70-kilogram human contains 43 kilograms of oxygen, mostly in the form of water and other oxides. Recently, the presence of frozen ice hs been observed on extra-terrestrial surface of Mars too.
- All animals need significant amounts of sulphur. Some amino acids, such as cysteine and methonine, contain sulphur. Plant roots take up sulphate ions from the soil and reduce them to sulphide ions. Metalloproteins use sulphur to attach to useful metal atoms in the body and sulphur similarly attaches itself to poisonous metal atoms like cadmium to haul them to the safety of the liver. On average, humans consume 900 milligrams of sulphur each day.
- All animals and some plants need trace amounts of selenium, but only for some specialized enzymes. Humans consume on average between 6 and 200 micrograms of selenium per day. Mushrooms are specially noted for their high selenium-content. Selenium in foods is most commonly found in the form of amino acids such as selenocysteine and selenomethionine. These are notably two animo acids having a matallic atom. The rest have carbon, hydrogen, oxygen and nitrogen along with sulphur in few of them. Selenium presence provides protection against heavy metal poisoning.
- Tellurium is not known to be needed for animal life and so also polonium has no biological role, and is highly toxic on account of it being radioactive.

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Chapter 13

PNICTOGENS, MEMBERS OF NITROGEN FAMILY

Pnictogens, their position in periodic table, their isotopes and allotropes, occurrence in nature, production of pinctogens, uses, Haber's process, Ostwald's process, propertres of pinctogens and their toxic effects.

Pnictogens : The Nitrogen group is Group 15 of the periodic table (formerly numbered as Group V or Group VA) opt is also collectively named the pnicogens or pnictogens consisting of nitrogen (N), phosphorus (P), arsenic (As), antimony (Sb), bismuth (Bi) and ununpentium (Uup) (which is quite unconfirmed). Some of the features of this family are :

- Nitrogen family elements consist of atoms having 5 electrons in their outer energy level.
- As you move down the nitrogen family: atomic radius increases, ionic radius increases, ionization energy decreases, and electronegativity decreases.
- Nitrogen family elements often form covalent compounds, usually with the oxidation number +3 or +5.
- Nitrogen and phosphorus are non-metals. Arsenic and antimony are metalloids. Bismuth is a metal.
- Except for nitrogen, the elements are solid at room temperature.
- Except for nitrogen and bismuth, the elements exist in two or more allotropic forms.

Character	N	P	As	Sb	Bi
Melting point (°C)	-209.86	44.1	817 (27 atm)	630.5	271.3
Boiling point (°C)	-195.8	280	613 (sublimes)	1750	1560
Density (g/cm^3)	1.25 x 10^{-3}	1.82	5.727	6.684	9.80
Ionization energy (kJ/mol)	1402	1012	947	834	703
Atomic radius (pm)	75	110	120	140	150
Ionic radius (pm)	146 (N^{3-})	212 (P^{3-})	—	76 (Sb^{3+})	103 (Bi^{3+})
Oxidation number	-3, +3, +5	-3, +3, +5	+3, +5	+3, +5	+3
Hardness (Mohs)	none (gas)	—	3.5	3.0	2.25
Crystal structure	cubic (solid)	cubic	rhombo-hedral	hcp	rhombo-hedral

- **Occurrence of pnictogens :** Nitrogen makes up 25 parts per million of the earth's crust, 5 parts per million of soil on average,

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100 to 500 parts per trillion of sea water and 78% of dry air. The majority of nitrogen on the earth is in the form of nitrogen gas, but some nitrate minerals do exist. Nitrogen makes up 2.5% of a typical human by weight.

- Phosphorus makes up 0.1% of the earth's crust as the 11th most abundant element. It makes up 0.65 parts per million of soil, and 15 to 60 parts per billion of seawater. There are 200 million metric tons of accessible phosphates on the earth. Phosphorus makes up 1.1% of a typical human by weight. Phosphorus occurs in minerals of the apatite family, the main components of the phosphate rocks.
- Arsenic makes up 1.5 parts per million of the earth's crust as the 53rd most abundant element. The soils contain 1 to 10 parts per million of arsenic, and seawater contains 1.6 parts per billion of it. Arsenic makes up 100 parts per billion of a typical human by weight. Some arsenic exists in elemental form, but most arsenic is found in the arsenic minerals: orpiment, realgar, arsenopyrite, and enargite.
- Antimony makes up 0.2 parts per million of the earth's crust as the 63rd most abundant element. The soils contain 1 part per million of antimony on average, and seawater contains 300 parts per trillion of antimony on average. A typical human contains 28 parts per billion of antimony by weight. Some elemental antimony occurs in silver deposits.
- Bismuth makes up 48 parts per billion of the earth's crust as the 70th most abundant element. The soils contain approximately 0.25 parts per million of bismuth, and seawater contains 400 parts per trillion of it. Bismuth most commonly occurs as the mineral bismuthinite, but also occurs in elemental form or in sulphide ores.

Production of pnictogens :

- **Nitrogen :** It is produced by fractional distillation of liquid air.
- **Phosphorus :** The principal method for producing phosphorus is to reduce phosphates with carbon in an electric arc furnace.
- **Arsenic**: Most of it is prepared by heating the mineral arsenopyrite in the presence of air. This forms As_4O_6, from which arsenic can be extracted via carbon reduction. However, it is also possible to make metallic arsenic by heating arsenopyrite at 650 to 700 °C without oxygen.
- **Antimony :** With sulphide ores, the method by which antimony is produced depends on the amount of antimony in the raw ore. If the ore contains 25% to 45% antimony by weight, then crude antimony is produced by smelting the ore in a blast furnace. If the ore contains 45% to 60% antimony by weight, it is obtained by heating the ore, also known as liquidation. Ores with more than 60% antimony by weight are chemically displaced with iron shavings from the molten ore, resulting in pure metal.
- If an oxide ore of antimony contains less than 30% antimony by weight, the ore is reduced in a blast furnace. If the ore contains closer to 50% antimony by weight, the ore is instead reduced in a reverberatory furnace.

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- Antimony ores with mixed sulphides and oxides are smelted in a blast furnace.
- **Bismuth :** Its minerals do occur, but it is more economic to produce bismuth as a by-product of lead. In China, bismuth is also found in tungsten and zinc ores.
- **Ununpentium :** It is produced in form of few atoms at a time in particle accelerators.
- **Preparation of nitrogen and its properties :** Nitrogen's uniqueness lies in its high electronegativity. It is commonly prepared using sodium dioxonitrate(III) solution and ammonium chloride solution.

$$NaNO_{2(aq)} + NH_4Cl_{(aq)} \rightarrow NH_4NO_{2(aq)} + NaCl_{(aq)}$$
$$NH_4NO_{2(aq)} \rightarrow N_{2(g)} + 2H_2O_{(l)}$$

It can also be produced by

- the action of chlorine on excess of ammonia.

$$3Cl_{2(g)} + 8NH_{3(g)} \rightarrow N_{2(g)} + 6NH_4Cl_{(s)}$$

- passing ammonia gas over heated copper(II)oxide.

$$2NH_{3(g)} + 3CuO_{(s)} \rightarrow 3Cu_{(s)} + 3H_2O_{(g)} + N_{2(g)}$$

- reduction of oxides of nitrogen by heated copper.

$$2Cu_{(s)} + 2NO_{(g)} \rightarrow 2CuO_{(s)} + N_{2(g)}$$

- **Ostwald's process :** The process involves the manufacture of nitric acid that takes place in three steps.

Ammonia oxidation	$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$	$\Delta H = -900\ kJmol^{-1}$
Nitric oxide oxidation	$2NO + O_2 \rightarrow 2NO_2$	$\Delta H = -115\ kJmol^{-1}$
	$2NO_2 \rightarrow N_2O_4$	$\Delta H = -58\ kJmol^{-1}$
Dinitrogen tetroxide	$3N_2O_4 + 2H_2O \rightarrow 4HNO_3 + 2NO$	$\Delta H = -103\ kJmol^{-1}$
Absorption		

as mixture	10% ammonia + 90% air
pressure	4 to 10 atmospheres
temperature	975 - 1225 K
catalyst	gauze of 90% platinum 10% rhodium
conversion	96%

- **Chemical properties :** The nitrogen atom has two s and three p electrons in its outermost shell. Three pairs of shared electrons bond the two atoms together in the N_2 molecule: (N≡ N).The great strength of this triple bond is responsible for the stability of the N_2 molecule and the consequent relative inertness of elementary nitrogen. The dissociation of 1 mole of N_2 molecules involves the absorption of very high energy (171 kcal). The same quantity of energy is released when 2 moles of nitrogen atoms form 1 mole of N_2molecules. This is the basic reason for the instability of many nitrogen compounds. Some of the compounds such as dynamite are so unstable that they decompose with explosive violence.
- Most chemical explosives are nitrogen compounds and elementary nitrogen is a product of their decomposition.

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Some reactions of nitrogen are :

- Nitrogen combines directly with certain metals, such as Ca, Al, Mg and Fe at very high temperatures and pressures, e.g., magnesium when red hot combines with nitrogen to form a magnesium nitride.

$$3Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$$

- when water is added to the nitride, it undergoes hydrolysis to liberate ammonia.

$$Mg_3N_{2(s)} + 6H_2O_{(l)} \rightarrow 3Mg(OH)_{2(s)} + 2NH_{3(g)}$$

- **Haber's process :** Nitrogen reacts with hydrogen and oxygen at high temperatures and pressures. With hydrogen - the reaction is reversible and in presence of a catalyst, it is used for producing ammonia.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

- Normally, pure iron powder is used as catalyst along with potassium hydroxide powder or molybednum as a promoter in Haber's process.
- With oxygen - at very high temperatures (about 200°C), nitrogen reacts with oxygen to form nitrogen(II)oxide.

$$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$

This reaction is also caused during thunder and lightning.

- **Phosphorous and its allotropes :** Some physical properties of three forms of phosphorus are given below.

Property	White phosphorus	Red phosphorus	Black Phosphorous
Colour	White, but turns yellow on exposure	Dark red	Black
State	Waxy solid, can be cut with knife	Brittle powder	Crystalline with greasy touch
Smell	Garlic smell	Odourless	
Density	1.84	2.1	2.69
Ignition temperature	307 K	533 K	673 K
Melting point	317 K	Does not melt	860K

$$P_4O_{10} + 10C \rightarrow 4P \text{ (white)} + 10CO$$

White phosphorous + 540K $\rightarrow$ Red phosphorous

White phosphorous + 670K $\rightarrow$ Black phosphorous

- **Preparation and properties of phosphorous :** The elemental phosphorus is extracted from calcium phosphate as given below at high temperatures of 1500 °C.

$$2\ Ca_3(PO_4)_2 + 6\ SiO_2 + 10\ C \rightarrow 6\ CaSiO_3 + 10\ CO + P_4$$

- White phosphorus was initially isolated on an industrial scale from bone ash. In the process, the tricalcium phosphate in bone ash is converted to monocalcium phosphate with sulphuric acid:

$$Ca_3(PO_4)_2 + 2\ H_2SO_4 \rightarrow Ca(H_2PO_4)_2 + 2\ CaSO_4$$

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- Monocalcium phosphate is then dehydrated to the corresponding metaphosphate:

$$Ca(H_2PO_4)_2 \rightarrow Ca(PO_3)_2 + 2\ H_2O$$

- When ignited to a white heat with charcoal, calcium metaphosphate yields two-thirds of its weight of white phosphorus while one-third of the phosphorus remains in the residue as calcium orthophosphate:

$$3\ Ca(PO_3)_2 + 10\ C \rightarrow Ca_3(PO_4)_2 + 10\ CO + P_4$$

Phosphorus(V) compounds

- **Oxides :** The most prevalent compounds of phosphorus are derivatives of phosphate (PO_4^{3-}), a tetrahedral anion. Phosphate is the conjugate base of phosphoric acid, which is produced on a massive scale for use in fertilisers. Being triprotic, phosphoric acid converts stepwise to three conjugate bases:

$$H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^{2-} \qquad K_{a1} = 7.25\times10^{-3}$$
$$H_2PO_4^{-} + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-} \qquad K_{a2} = 6.31\times10^{-8}$$
$$HPO_4^{2-} + H_2O \rightleftharpoons H_3O^+ + PO_4^{2-} \qquad K_{a3} = 3.98\times10^{-13}$$

- Phosphate exhibits the tendency to form chains and rings with P-O-P bonds. Many polyphosphates are known, including ATP. Polyphosphates arise by the dehydration of hydrogen phosphates such as HPO_4^{2-} and $H_2PO_4^{-}$. For example, the industrially important trisodium triphosphate is produced industrially by the condensation reaction as:

$$2\ Na_2[(HO)PO_3 + Na[(HO)_2PO_2 \rightarrow [Na_5[O_3P\text{-}O\text{-}P(O)_2\text{-}O\text{-}PO_3] + 2\ H_2O$$

- Phosphorus pentoxide (P_4O_{10}) is the acid anhydride of phosphoric acid, but several intermediates between the two are known. This waxy white solid reacts vigorously with water.
- With metal cations, phosphate forms a variety of salts. These solids are polymeric, featuring P-O-M linkages. When the metal cation has a charge of 2+ or 3+, the salts are generally insoluble, hence, they exist as common minerals. Many phosphate salts are derived from hydrogen phosphate (HPO_4^{2-}).
- PCl_5 and PF_5 are common compounds. PF_5 is a colourless gas and the molecules have trigonal bypramidal geometry. PCl_5 is a colourless solid which has an ionic formulation of $PCl_4^+ PCl_6^-$, but adopts the trigonal bypramidal geometry when molten or in the vapour phase.
- PBr_5 is an unstable solid formulated as $PBr_4^+Br^-$ and PI_5 is not known. Pentachloride and pentafluoride are Lewis acids. With fluoride, PF_5 forms PF_6^-, an anion that is isoelectronic with SF_6. The most important oxyhalide is phosphorus oxychloride, ($POCl_3$), which is approximately tetrahedral.
- **Nitrides :** The PN molecule is considered unstable, but is a product of crystalline phosphorus nitrides decompose at 1100 K. Similarly, H_2PN is considered unstable, and phosphorus nitride halogens like F_2PN, Cl_2PN, Br_2PN and I_2PN oligomerise into cyclic polyphosphazenes. For example, compounds of the formula

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$(PNCl_2)_n$ exist mainly as rings such as the trimer hexa-chlorophosphazene. The phosphazenes arise by the treatment of phosphorus pentachloride with ammonium chloride :

$PCl_5 + NH_4Cl \rightarrow 1/n\ (NPCl_2)_n + 4HCl$

- When the chloride groups are replaced by alkoxide (RO^-), a family of polymers is produced with potentially useful properties.
- **Sulphides** : Phosphorus forms a wide range of sulphides, where the phosphorus can be in P(V), P(III) or posses other oxidation states. The most famous is the three-fold symmetric P_4S_3, used in strike-anywhere matches. P_4S_{10} and P_4O_{10} have analogous structures.
- **Phosphorus(III) compounds :** All four symmetrical trihalides are well known: gaseous PF_3, the yellowish liquids PCl_3 and PBr_3, and the solid PI_3. These materials are moisture sensitive, hydrolysing to give phosphorous acid. The trichloride, a common reagent, is produced by the chlorination of white phosphorus: $P_4 + 6\ Cl_2 \rightarrow 4\ PCl_3$
- The trifluoride is produced from the trichloride by halide exchange. PF_3 is toxic because it binds to haemoglobin.
- Phosphorus(III) oxide, P_4O_6 (also called tetraphosphorus hexoxide), is the anhydride of $P(OH)_3$, the minor tautomer of phosphorous. acid. The structure of P_4O_6 is like that of P_4O_{10} without the terminal oxide groups. However, mixed oxyhalides and oxyhydrides of phosphorus(III) are almost unknown.
- **Organophosphorus compounds :** Compounds with P-C and P-O-C bonds are often classified as organophosphorus compounds. They are widely used commercially. The PCl_3 serves as a source of P^{3+} in routes to organophosphorus(III) compounds. For example, it is the precursor to triphenylphosphine:

$$PCl_3 + 6\ Na + 3\ C_6H_5Cl \rightarrow P(C_6H_5)_3 + 6\ NaCl$$

- Treatment of phosphorus trihalides with alcohols and phenols gives phosphites, e.g., triphenylphosphite:

$$PCl_3 + 3\ C_6H_5OH \rightarrow P(OC_6H_5)_3 + 3\ HCl$$

- Similar reactions occur for phosphorus oxychloride, affording triphenylphosphate:

$$OPCl_3 + 3\ C_6H_5OH \rightarrow OP(OC_6H_5)_3 + 3\ HC$$

- Phosphorous reacts with itself readily to form the allotropes: white phosphorous, red phosphorous and black phosphorous, Phosphorous also reacts readily with oxygen and hydrogen, although it is able to react with almost any element on the periodic table. Red phosphorous can be reacted with metals in an inert atmosphere to form either metal or phosphorous-rich phosphides.
- Red phosphorous can be reacted with metals in an inert atmosphere to form either metal or phosphorous rich phosphides.
- **Organometallic Compounds :** All three elements form a wide range of organometallic compounds in both the +3 and +5 state. It can form both M-C single bonds and M=C double bonds. Stability of M-C bond strength decreases in the order of As > Sb > Bi, Aryl compounds are more stable than alkyl compounds.

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- Compounds of As, Sb and Bi with the metals of group III (Al, Ga, I)

Uses of pnictogens :

- Liquid nitrogen is a commonly used as cryogenic liquid.
- Nitrogen in the form of ammoniun ions is a nutrient critical to the survival of most plants'.
- Phosphorus is used in matches (Phoshporous sulphide) and incendiary bombs.
- Phosphate fertilizer helps feed much of the world.
- Arsenic was historically used as a Paris green pigment, but is not used this way any more, due to its extreme toxicity.
- Arsenic in the form of organoarsenic compounds is sometimes used in chicken feed.
- Antimony is alloyed with lead to produce bullets.
- Antimony currency was briefly used in the 1930s in parts of China, but this use was discontinued as antimony is soft and toxic.
- Bismuth subsalicylate is the active ingredient in Pepto-Bismol.

Toxic effects of pnictogens :

- Nitrogen gas is completely non-toxic, but breathing in pure nitrogen gas is deadly, because it causes nitrogen asphyxiation. The build up of nitrogen bubbles in the blood, such as during deep-sea diving, can cause a condition known as the "bends" (decompression sickness). Many nitrogen compounds, such as hydrogen cyanide and explosives are also highly dangerous.
- White phosphorus, an allotrope of phosphorus, is toxic, with 1 milligram per kilo bodyweight being a lethal dose. White phosphorus usually kills humans within a week of ingestion by attacking the liver. Breathing in phosphorus in its gaseous form can cause an industrial disease called "phossy jaw", which eats away the jawbone. White phosphorus is also highly inflammable.
- Elemental arsenic is toxic, as are many of its inorganic compounds; however, some of its organic compounds can promote growth in chickens. The lethal dose of arsenic for a typical adult is 200 milligrams, and can cause diarrhoea, vomiting, colic, dehydration and coma. Death from arsenic poisoning typically occurs within a day.
- Antimony is mildly toxic. Additionally, wine steeped in antimony containers can induce vomiting. If taken in large doses, antimony causes vomiting in a victim, who then appears to recover before dying several days later. Antimony attaches itself to certain enzymes and is difficult to dislodge. Stibine, or SbH_3 is far more toxic than pure antimony.
- Bismuth itself is largely non-toxic, although consuming too much of it can damage the liver. However, consumption of soluble bismuth salts can turn a person's gums black.

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Chapter 14

HALOGENS

Halogens, their position in periodic table, their physical properties, methods of preparation, isotopes, their distinguishing properties, chemical properties, interhalogen compounds and superhalogen compounds, industrial uses, uses in maintaining human health, their toxicity.

Halogen	Standard atomic weight (u)	Melting point (K)	Boiling point (K)	Density (g/cm³) at 25°C	Electro-negativity (Pauling)	First Ionization energy (kJ.mol⁻¹)	Covalent radius (pm)
Fluorine	18.998	53.53	85.03	0.0017	3.98	1681.0	71
Chlorine	[35.446; 35.457]	171.6	239.11	0.0032	3.16	1251.2	99
Bromine	79.904	265.8	332.0	3.1028	2.96	1139.9	114
Iodine	126.9044	386.85	457.4	4.933	2.66	1008.4	133
Astatine	[210]	575	?610	?6.2–6.5	2.2	?887.7	?

Halogens : These are in a group in the periodic table consisting of five chemically related elements : fluorine (F), chlorine (Cl), bromine (Br), iodine (I) and astatine (At). The artificially created element 117 (ununseptium) may also be a halogen.

- **Oxidising and reducing strength of halogens :** There is a regular decrease in the oxidizing strength of the halogens from fluorine to iodine.
  Oxidising strength: $F_2 > Cl_2 > Br_2 > I_2$
- This trend is mirrored by an increase in the reducing strength of the corresponding halides.
  Reducing strength: $I^- > Br^- > Cl^- > F^-$
- **Methods of preparing the Halogens from their Halides :** The halogens can be made by reacting a solution of the halide ion with any substance that is a stronger oxidizing agent. Iodine, for example, can be made by reacting the iodide ion with either bromine or chlorine.
  $2\,I^-(aq) + Br_2(aq) \rightarrow I_2(aq) + 2\,Br^-(aq)$
  Bromine is prepared by reacting bromide ions with a solution of Cl_2 dissolved in water.
  $2\,Br^-(aq) + Cl_2(aq) \rightarrow Br_2(aq) + 2\,Cl^-(aq)$
  To prepare Cl_2, we need a particularly strong oxidizing agent, such as manganese dioxide (MnO_2).
  $2\,Cl^-(aq) + MnO_2(aq) + 4\,H^+(aq) \rightarrow Cl_2(aq) + Mn^{2+}(aq) + 2\,H_2O(l)$

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- The best way of producing a strong reducing agent is to pass an electric current through a salt of the metal. Sodium, for example, can be prepared by the electrolysis of molten sodium chloride.

$$2\ NaCl(l) \xrightarrow{\text{electrolysis}} 2\ Na(s) + Cl_2(g)$$

The same process is used for generating strong oxidizing agents, such as F_2.

- Attempts to prepare fluorine by electrolysis failed until 1886 when Henri Moissan successfully isolated F_2 gas from the electrolysis of a mixed salt of KF and HF and noted that the crystals of silicon burst into flame when mixed with this gas. Electrolysis of KHF_2 is still used to prepare fluorine today.

$$2\ KHF_2(s) \xrightarrow{\text{electrolysis}} H_2(g) + F_2(g) + 2\ KF(s)$$

- **Fluorine :** It is one of the most reactive elements being the most electronegative in nature. Flourine is a chemical element with symbol F and atomic number 9. It is the strongest halogen & exists as a highly toxic pale yellow diatomic gas at standard conditions. It can react with otherwise-inert materials such as glass, and forming compounds with the usually inert noble gases. It is a corrosive and highly toxic gas. The reactivity of fluorine is such that, if used or stored in laboratory glassware, it can react with glass in the presence of small amounts of water to form silicon tetrafluoride (SiF_4). Hence, HF (Hydrofluoric acid) is used for the scratching of glass. It needs to be handled with care and stored in substances such as Teflon (which is itself an organofluorine compound), extremely dry glass or metals such as copper or steel, which form a protective layer of fluoride on their surface.
- **Hydrogen halides :** All of the halogens react with hydrogen to form hydrogen halides. For fluorine, chlorine and bromine, this reaction is in the form of:

$$H_2 + X_2 \rightarrow 2HX$$

However, hydrogen iodide and hydrogen astatide can split back into their constituent elements. The hydrogen-halogen reactions get gradually less reactive towards the heavier halogens. A

- fluorine-hydrogen reaction is explosive even when it is dark and cold.
- chlorine-hydrogen reaction is also explosive, but only in the presence of light and heat.
- bromine-hydrogen reaction is even less explosive it is explosive only when exposed to flames.
- **Metal halides :** All the halogens are known to react with sodium to form sodium fluoride, sodium chloride, sodium bromide, sodium iodide and sodium astatide. Heated sodium's reaction with halogens produces bright-orange flames. Sodium's reaction with chlorine is in the form of:

$$2Na + Cl_2 \rightarrow 2NaCl$$

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- Iron reacts with fluorine, chlorine and bromine to form Iron (III) halides. These reactions are:

$$2Fe + 3X_2 \rightarrow 2FeX_3$$

- However, when iron reacts with iodine, it forms only iron(II) iodide.
- Iron wool can react rapidly with fluorine to form the white compound iron(III) fluoride even in cold temperatures.
- When chlorine comes into contact with heated iron, they react to form the black iron (III) chloride. However, in moist conditions, this reaction produces a reddish-brown product.
- Iron can also react with bromine to form iron(III) bromide. This compound is reddish-brown in dry conditions. Hot iron can also react with iodine, but it forms iron(II) iodide.
- **Interhalogen compounds :** These compounds are in the form of XY_n where X and Y are halogens and *n* is either one, three, five or seven. These compounds contain at most two different halogens. Large interhalogens, such as ClF_3, can be produced by a reaction of a pure halogen with a smaller interhalogen such as ClF. All interhalogens except IF_7 can be produced by directly combining pure halogens in various conditions.
- Bromine reacts with chlorine, for example, to give BrCl, which is a gas at room temperature.

$$Br_2(l) + Cl_2(g) \rightarrow 2\ BrCl(g)$$

- Interhalogen compounds with the general formulas XY_3, XY_5 and even XY_7 are formed when the pairs of halogens react. Chlorine reacts with fluorine, for example, to form chlorine trifluoride.

$$Cl_2(g) + 3\ F_2(g) \rightarrow 2\ ClF_3(g)$$

- ClF_3 and BrF_5 are extremely reactive compounds. ClF_3 is so reactive that wood, asbestos and even water spontaneously burn in its presence. These compounds are excellent fluorinating agents, which tend to react with one another to form positive ions such as ClF_2^+ and BrF_4^+ and negative ions such as IF_2^- and BrF_6^-.

$$2\ BrF_5(l) \rightarrow [BrF_4^+][BrF_6^-](s)$$

- Interhalogens are more reactive than all diatomic halogen molecules except F_2 because interhalogen bonds are weaker. However, the chemical properties of interhalogens are still roughly the same as those of diatomic halogens. Many interhalogens consist of one or more atoms of fluorine bonding to a heavier halogen. Chlorine can bond with up to 3 fluorine atoms, bromine can bond with up to five fluorine atoms, and iodine can bond with up to seven fluorine atoms. Most of these compounds are covalent gases. However, there are some interhalogens that are liquids, such as BrF_3, and many iodine-containing interhalogens are solids.

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Reactions with water :

- Fluorine reacts vigorously with water to produce oxygen (O_2) and hydrogen fluoride (HF)

$$2\ F_2(g) + 2\ H_2O(l) \rightarrow O_2(g) + 4\ HF(aq)$$

- Chlorine has maximum solubility of 7.1 g Cl_2 per kg of water at ambient temperature (21 °C). Dissolved chlorine reacts to form hydrochloric acid (HCl) and hypochlorous acid, a solution, that can be used as a disinfectant or bleach:

$$Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$$

- Bromine has a solubility of 3.41 g per 100 g of water, but it slowly reacts to form hydrogen bromide (HBr) and hypobromous acid (HBrO):

$$Br_2(g) + H_2O(l) \rightarrow HBr(aq) + HBrO(aq)$$

- Iodine, however, is minimally soluble in water (0.03 g/100 g water at 20 °C) and does not react with it. However, it forms an aqueous solution in the presence of iodide ion, such as by addition of potassium iodide (KI), because of the formation of the triiodide ions.
- **Testing halogens :** The solution is acidified by adding dilute nitric acid. The nitric acid reacts and removes other ions that might also form precipitates with silver nitrate. Silver nitrate solution is then added, and the halide can be identified from the following products:

Ions present	Observation	Ions present	Observation
Fluoride ions	No precipitate	**Bromide ions**	Pale cream precipitate
Chloride ions	White precipitate	**Iodide ions**	Pale yellow precipitate

- **Confirming the precipitate using ammonia solution :** Ammonia solution is added to the precipitates.

Original precipitate	Observation
AgCl	Precipitate dissolves to give a colourless solution.
AgBr	Precipitate remains almost unchanged in dilute ammonia solution but dissolves completely in concentrated ammonia solution.
AgI	Precipitate remains almost unchanged both in dilute and concentrated solution.

- **An alternative test using concentrated sulphuric acid :** Adding concentrated sulphuric acid to a solid sample of one of the halides gives the following results:

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Ion present	Observation
Fluoride	Steamy acidic fumes of HF
Chloride	Steamy acidic fumes of HCl
Bromide	Steamy acidic fumes of HBr with brown vapour of bromine.
Iodide	Steamy acidic HI fumes with purple iodine vapour and a red compound in the reaction vessel.

Isotopes of halogens :

- Fluorine has one stable and naturally occurring isotope, F-19.
- **Chlorine :** It has two stable and naturally occurring isotopes, chlorine-35 and chlorine-37. However, there are trace amounts in nature of the isotope chlorine-36, which occurs via spallation of argon-36.
- **Bromine :** There are two stable and naturally occurring isotopes of bromine, bromine-79 and bromine-81.
- **Iodine :** There is one stable and naturally occurring isotope of iodine, iodine-127. However, there are trace amounts in the nature of the radioactive isotope iodine-129, which occurs via spallation and from the radioactive decay of uranium in ores.
- **Astatine :** There are no stable isotopes of astatine. However, there are three naturally occurring radioactive isotopes of astatine produced via radioactive decay of uranium, neptunium and plutonium. These isotopes are astatine-215, astatine-217 and astatine-219 respectively.
- **Superhalogen :** Certain aluminium clusters have superatom properties. These aluminium clusters are generated as anions (Al_n with n= 1, 2, 3, ...) in helium gas and reacted with a gas containing iodine. When analyzed by mass spectrometry, one main reaction product turns out to be Al_{131}.The cluster component in the 'Al_{131}' ion is similar to an iodide ion or a bromide ion. The related 'Al_{131}' cluster is expected to behave chemically like the triiodide ion.

Uses of halogens :

- Both chlorine and bromine are used as disinfectants for drinking water, swimming pools, fresh wounds, dishes and surfaces. They kill bacteria and other potentially harmful microorganisms through a process known as sterilization. Their reactivity is also put to use in bleaching.
- Sodium hypochlorite, which is produced from chlorine, is the active ingredient of most fabric bleaches, and chlorine-derived bleaches are used in the production of some paper products.
- Chlorine (Cl_2) is a highly toxic gas with a pale yellow-green colour. It reacts with sodium to produce sodium chloride, the table salt. Large

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quantities of chlorine are used every year to make solvents such as carbon tetrachloride (CCl_4), chloroform ($CHCl_3$), dichloroethylene ($C_2H_2Cl_2$) and trichloroethylene (C_2HCl_3).

- Bromine (Br_2) is a reddish-orange liquid with an unpleasant, choking odour. Bromine is used for preparing flame retardants, fire-extinguishing agents, sedatives, antiknock agents for gasoline, and insecticides.
- Iodine (I_2) is an intensely coloured solid with an almost metallic luster. This solid is relatively volatile, and it sublimes when heated to form a violet-coloured gas. Iodine has been used for many years as a disinfectant in "tincture of iodine." Iodine compounds are used as catalysts, drugs and dyes. Silver iodide (AgI) plays an important role in the photographic process and in attempts to make rain by seeding clouds. Iodide is also added to salt to protect against goitre an iodine deficiency disease characterized by a swelling of the thyroid gland.
- Halogen lamps are a type of incandescent lamp using a tungsten filament in a bulb that has a small amount of a halogen, such as iodine or bromine added. This enables the production of lamps that are much smaller than non-halogen incandescent light bulbs at the same wattage. The gas reduces the thinning of the filament and blackening of the inside of the bulb resulting in a bulb that has a much greater life. Halogen lamps glow at a higher temperature (2800 to 3400 Kelvin) with a whiter colour than other incandescent bulbs.
- In drug discovery, the incorporation of halogen atoms into a lead drug candidate results in analogues.
- That are usually more lipophilic and less water-soluble. As a consequence, halogen atoms are used for improving penetration through lipid membranes and tissues. It follows that there is a tendency for some halogenated drugs to accumulate in adipose tissue.

Uses of halogens to living organisms :

- Fluoride anions are found in ivory, bones, teeth, blood, eggs, urine and hair of organisms. Fluoride anions in very small amounts are essential for humans. There is 0.5 milligram of fluorine per litre of human blood. Human bones contain 0.2 to 1.2% fluorine. A typical 70-kilogram human contains 3 to 6 grams of fluorine.
- Chloride anions are essential to both plants and humans. Human blood contains an average of 0.3% chlorine that helps maintain ionic balance with sodium or potassium ions, in the secretion of HCl in stomach, etc. There is a total of 95 grams of chlorine in a typical 70-kilogram human.

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- A biological role for bromine in humans has not been proven, but some organisms contain organobromine compounds. Humans typically consume 1 to 20 milligrams of bromine per day. A typical 70-kilogram human contains 260 milligrams of bromine.
- Humans typically consume less than 100 micrograms of iodine per day. Iodine deficiency can cause intellectual disability. Organo-iodine compounds occur in humans in some of the glands, such as in the thyroid gland and the stomach, epidermis and immune system. Foods containing iodine include cod, oysters, shrimp, herring, lobsters, sunflower seeds, seaweeds and mushrooms. There are 10 to 20 milligrams of iodine in a typical 70-kilogram human.
- Astatine being radioactive has no biological role.

Toxic effects of halogens on human health : Halogens tend to decrease in toxicity towards the heavier halogens.

- Fluorine gas is extremely toxic; breathing fluorine gas at a concentration of 0.1% for several minutes is lethal. Hydrofluoric acid is also toxic, being able to penetrate skin and cause highly painful burns. However, it is widely used for etching glass i.e. writing or drawing on glass furface.
- Fluorine (F_2), a lethal, colourless gas, is the most reactive element known so reactive that asbestos, water and silicon burst into flame in its presence. It is so reactive that it even forms compounds with Kr, Xe and Rn. Such as xenon fluorides and krypton fluorides. Fluorine is such a powerful oxidizing agent that it can coax other elements into unusually high oxidation numbers, as in AgF_2, PtF_6 and IF_7.
- Fluorine is so reactive that it is difficult to find a container in which it can be stored. F_2 attacks both glass and quartz, for example, and causes most metals to burst into flame. Fluoride can be lethal in amounts of 5 to 10 grams. Prolonged consumption of fluoride above concentrations of 1.5 mg/L is associated with a risk of dental fluorosis, and skeletal fluorosis, a condition in which bone fractures become more common due to the hardening of bones. Current recommended levels in water fluoridation, a way to prevent dental caries, range from 0.7 to 1.2 mg/L. People with levels between normal levels and those required for skeletal fluorosis tend to have symptoms similar to arthritis.
- Chlorine gas is highly toxic. Breathing in chlorine at a concentration of 3 parts per million can rapidly cause a toxic reaction and can prove fatal.
- Pure bromine is somewhat toxic, but less toxic than fluorine and chlorine. One hundred milligrams of bromine is lethal. Bromide anions are also toxic, but less than bromine. Bromide has a lethal dose of 30 grams.
- Iodide anions are mostly non-toxic, but these can become deadly if ingested in large amounts.
- Astatine being radioactive is highly dangerous.

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Chapter 15

TRANSITION ELEMENTS

Transition elements, difference in transition metals with respect to others, list of transition elements in three different series with physical properties, coloured compounds formed by transition elements, transition elements and magnetic behaviour, inner transition elements, lanthanoids also called rare earth metals, actinoids and their uses.

Transition elements : The elements in the periodic table are often divided into four categories: (1) main group elements, (2) transition metals, (3) lanthanides and (4) actinides. The *main group elements* include the active metals in the two columns on the extreme left of the periodic table and the metals, semimetals and non-metals in the six columns on the far right. The transition metals are the metallic elements that serve as a bridge or transition between the two sides of the table. The *lanthanoids* and the *actinoids* at the bottom of the table each with 14 elements are sometimes known as the *inner transition metals* because they have atomic numbers that fall between the first and second elements in the last two rows of the transition metals.

Main-group Elements		Transition Metals										Main-group Elements					
H																	
Li	Be															H	He
Na	Mg											B	C	N	O	F	Ne
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Al	Si	P	S	Cl	Ar
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ca	Ph	Pb	Ag	Cd	Ga	Ge	As	Se	B	Kr
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	In	Sn	Sb	Te	I	Xe
Fr	Ra	Ac	Rf	Ha	106	107	108	109				Tl	Pb	Bi	Po	At	Rn

Lanthanides	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Actinides	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Li

- The transition elements may be subdivided according to the electronic structures of their atoms into three main transition series, called the first, second and third transition series, and two inner transition series, called the lanthanoids and the actinoids.
- The first main transition series begins with either scandium (symbol Sc, atomic number 21) and ends with zinc (symbol Zn, atomic number 30).

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- The second series includes the elements yttrium (symbol Y, atomic number 39) and cadmium (symbol Cd, atomic number 48).
- The third series extends from lanthanum (symbol La, atomic number 57) to mercury (symbol Hg, atomic number 80).
- These three main transition series are included in the set of 30 elements often called the *d*-block transition elements. Because scandium, yttrium and lanthanum actually do not form compounds analogous to those of the other transition elements and because their chemistry is quite homologous to that of the lanthanoids,
- Zinc, cadmium and mercury exhibit few of the properties characteristic of the other transition elements, they are treated separately. The remaining *d*-block transition elements and some of their characteristic properties are listed in the Table given below.

Some properties of the transition elements

	Symbol	Atomic number	Atomic mass	Density (g/cm3 20 °C)	Melting point(°C)	Boiling point(°C)
1st main series						
Titanium	Ti	22	47.867	4.54	1,668	3,287
Vanadium	V	23	50.942	6.11	1,910	3,407
Chromium	Cr	24	51,996	7.14	1,907	2,672
Manganese	Mn	25	54.938	7.21–7.44	1,246	2,061
Iron	Fe	26	55.845	7.87	1,538	2,861
Cobalt	Co	27	58.933	8.9	1,495	2,927
Nickel	Ni	28	58.693	8.9	1,455	2,913
Copper	Cu	29	63.546	8.92	1,085	2,927
2nd main series						
Zirconium	Zr	40	91.224	6.51	1,855	4,409
Niobium	Nb	41	92.906	8.57	2,477	4,744
Molybdenum	Mo	42	95.94	10.22	2,623	4,639
Technetium	Tc	43	98	11.5	2,157	4,265
Ruthenium	Ru	44	101.07	12.41	2,334	4,150
Rhodium	Rh	45	102.906	12.41	1,964	3,695
Palladium	Pd	46	106.42	12.02	1,555	2,963
Silver	Ag	47	107.868	10.49	962	2,162
3rd main series						
Hafnium	Hf	72	178.49	13.31	2,233	4,603
Tantalum	Ta	73	180.948	16.65	3,017	5,458
Tungsten	W	74	183.84	19.3	3,422	5,555
Rhenium	Re	75	186.207	21.02	3,186	5,596
Osmium	Os	76	190.23	22.57	3,033	5,012

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Iridium	Ir	77	192.217	22.56	2,446	4,428
Platinum	Pt	78	195.084	21.45	1,768	3,825
Gold	Au	79	196.967	~19.3	1,064	2,856

- The first of the inner transition series includes the elements from cerium (Ce, atomic number 58) to lutetium (Lu, atomic number 71). These elements are called the lanthanoids (or lanthanides) because the chemistry of each closely resembles that of lanthanum. Lanthanum itself is often regarded as one of the lanthanoids. The actinoid series consists of 15 elements from actinium (Ac, atomic number 89) to lawrencium (Lr, atomic number 103). These inner transition series are covered under rare earth element and actinoid element.
- The most abundant transition element in the earth's solid crust is iron, which is fourth among all elements and second (to aluminium) among metals in crustal abundance. The elements titanium, manganese, zirconium, vanadium and chromium also have abundance in excess of 100 grams (3.5 ounces) per ton. Some of the most important and useful transition elements have very low crystal abundance e.g., tungsten, platinum, gold and silver.
- **Transition metals as catalysts :** One important use of transition metals and their compounds is as catalysts for a variety of industrial processes, mostly in the petroleum and polymer (plastics, fibres) industries, in which organic molecules are isomerized, built up from simple molecules, oxidized, hydrogenated or caused to polymerize.
- **Chromium :** It is a transition element with symbol cr & atomic number 24.
- Chromium trioxide dispersed on silica-alumina, catalyzes polymerizing ethylene.
- Chromium in the form of chromium sesquioxide, or chromic oxide, on alumina is the major industrial catalyst for transforming saturated hydrocarbons to useful olefins such as *n*-butane to butylene and butadiene.
- **Iron**-containing catalysts are used in various processes such as producing ammonia from nitrogen and hydrogen.(Haber's process). This process, developed early in the 20th century, represents the first major industrial application of transition metal catalysis.
- Molybdenum in molybdenum trioxide–aluminum oxide mixtures or in cobalt oxide–molybdenum trioxide–aluminum oxide mixtures finds many applications, such as desulphurizing gases and liquids; removing lead, nickel and vanadium from petroleum refinery feed stocks; and in modifying, or "reforming," crude petroleum fractions to increase their octane rating.
- Nickel preparations as catalysts are used in the hydrogenation of unsaturated hydrocarbons such as in the production of vanaspati ghee, at atmospheric pressure and room temperature. It is slowly oxidized by air at room temperature & is considered corrosion resistant.
- Copper is a component of a variety of catalysts, of which the copper chromites, are used for the selective hydrogenation of carbonyl groups. Fats and oils can also be hydrogenated to alcohols using copper catalysts. Palladium chloride together with the salts of copper in the +1 oxidation state forms a homogeneous catalyst for oxidizing ethylene to acetaldehyde.

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- Metallic platinum has a broad spectrum of catalytic activities. One of the most important in terms of tonnage production is used in catalytic reforming of petroleum fractions to improve the anti-knock quality of gasoline.
- Silver oxide, on an inactive, refractory support, catalyzes the oxidation of ethylene to ethylene oxide.
- The oxo process (also called hydroformylation), in which certain olefins react with carbon monoxide and hydrogen to give aldehydes (a class of organic compounds that contain the group "CHO), requires a homogeneous catalyst containing a transition metal. More recently rhodium complexes have been found to have greater activity at lower temperatures and pressures.
- Transition metals and coloured compounds: The unique structure of the transition metals causes them to form brightly coloured compounds. This structure affects the way light is absorbed, transmitted and reflected. The oxidation state of the particular element affects the colour of the compounds it gives.

Wavelength of light absorbed versus colour observed:

- 400nmViolet absorbed, Green-yellow observed (λ = 560nm)
- 450nm Blue absorbed, Yellow observed (λ = 600nm)
- 490nm Blue-green absorbed, Red observed (λ = 620nm)
- 570nm Yellow-green absorbed, Violet observed (λ = 410nm)
- 580nm Yellow absorbed, Dark blue observed (λ = 430nm)
- 600nm Orange absorbed, Blue observed (λ = 450nm)
- 650nm Red absorbed, Green observed (λ = 520nm)

Wavelength (nm)	Colour	Complementary colour
400 – 424	Violet	Green-yellow
424 – 491	Blue	Yellow
491 – 570	Green	Violet
570 – 585	Yellow	Blue
585 – 647	Orange	Cyan-blue
647 – 700	Red	Cyan

- The most important coloured ions are listed in the table given below.

Transition Metal Ion	Colour	Transition Metal Ion	Colour
Co^{2+}	Pink	Fe^{3+}	Brown to yellow
Cu^{2+}	Blue-green	CrO_4^{2-}	Orange
V^{4+}	Blue	$Cr_2O_7^{2-}$	Yellow
V^{3+}	Green	Ti^{3+}	Purple
Fe^{2+}	Olive green	Cr^{3+}	Violet
Ni^{2+}	Bright green	Mn^{2+}	Pale pink
Mn^{3+}	Violet	Zn^{2+}, Cd^{2+}, Sc^{3+}, Ti^{4+}	Colourless

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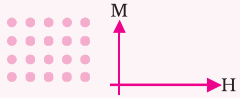
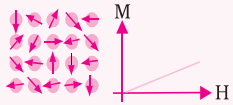
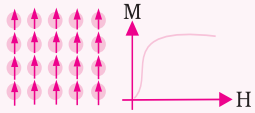
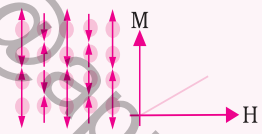
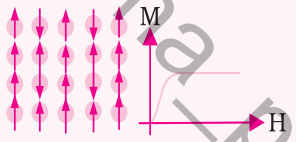
Transition elements and magnetic properties:

S. N.	Type of Magnetism	Susceptibility	Atomic / Magnetic Behaviour	Example / Susceptibility
1.	**Dia-magnetism**	Small & negative.	Atoms have no magnetic moment 	Au -2.74×10^{-6} Cu -0.77×10^{-6}
2.	**Para-magnetism**	Small & positive.	Atoms have randomly oriented magnetic moments 	β–Sn $.019\times10^{-6}$ Pt 21.04×10^{-6} Mn 66.10×10^{-6}
3.	**Ferro-magnetism**	Large & positive, function of applied field, microstructure dependent.	Atoms have parallel aligned magnetic moments 	Fe ~100,000
4.	**Antiferro-magnetism**	Small & positive.	Atoms have mixed parallel and anti-parallel aligned magnetic moments 	Cr 3.6×10^{-6}
5.	**Ferri-magnetism**	Large & positive, function of applied field, microstructure dependent	Atoms have anti-parallel magnetic moments 	Ba ferrite ~3

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- **Inner transition elements :** There are two series of elements known as the lanthanoids (lanthanides) and actinoids(actinides). They are usually shown below all the other elements in the standard view of the periodic table, but they really belong to periods 6 and 7.
- **Lanthanoids :** The lanthanoid series consists of the 14 elements cerium through lutetium (atomic numbers 58–71), which immediately follow lanthanum. Likewise, the actinoid series consists of the 14 elements thorium through lawrencium (atomic numbers 90–103), which immediately follow actinium. These elements were among the last to be discovered and placed in the periodic table. Actinoids which are all radioactive with uranium and plutonium as important elements include many which do not occur naturally but synthesized through nuclear reactions.
- In these elements *d* and *f* subshells lie close together in energy leading to some irregularities in electronic structure, hence, it was not certain to place them in the periodic table such as lanthanum and actinium have no electrons in their *f* subshells .
- Except cerium and europium, the lanthanoids occur naturally in ionic compounds with a 3+charge .
- **Lanthnoid contraction :** Going down the series, the atomic radii decrease, a phenomenon called lanthanoid contraction. The lanthanide contraction refers to the fact that the 5s and 5p orbitals penetrate the 4f sub-shell, so the 4f orbital is not shielded from the increasing nuclear charge, which causes the atomic radius of the atom to decrease. This decrease in size continues throughout the series.
- Lanthanoids resemble alkali metals in reaction with water like alkali metals releasing hydrogen as a byproduct.

Uses of lanthanoids :

- Most of lanthanoids are used in lasers and given that they can deflect UV rays and infra red rays, they are commonly used for making sunglasses.
- A number of lanthanoids such as cerium. neodymium and samarium are alloyed with other metals to form strong permanent magnets.
- Samarium and Lutetnium have radioactive isotopes that are used for dating minerals and rocks from the earth, meteorites and the moon.
- **Actinoids :** The 14 elements in actinoides series are from thorium to lawrencium. The elements show contraction like lanthanoids but it is not very regular like lanthoids. They have a wider range of oxidation states and most of them have a short half life other than uranium, thorium and plutonium with uranium ore found in the earth's crust.

Uses of actinoids : These are commonly used in nuclear reactor and used as fuel in nuclear weapons.

- Thorium is used for coating tungsten wiring in a electronic components.
- Technique called 'uranium-thorium dating' is used to determine the age of fossils.
- A smoke detector using the minute quantity of americanium is used for producing ionizing radiations.

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Chapter 16

METALLURGY

Mineral v/s ores, types of ores, concentration of ores, including froth floatation, leaching, etc. calcination, roasting, reduction of ores, electrolytic refining, leaching of ores of aluminium, silver and gold, smelting of iron, cupellation, zone refining, Mond's process, alloys, their types and uses.

- **Mineral v/s ore :** Anything obtained from the earth's crust containing a metal or soluble or insoluble salt is called a mineral. A mineral that can be used for extracting a metal profitably is called an ore. Hence, all ores are minerals but all minerals cannot be considered as ores. A mineral is a naturally occuring chemical compound, usually of crystalline form & abiogenic in origin.

Elements and their occurrence in ores

Combined state	Element	Name of the mineral
Oxide	Fe Al Mn	Haematite (Fe_2O_3), Magnetite ($Fe_2O_3.FeO$) Bauxite ($Al_2O_3.2H_2O$) Pyrolusite (MnO_2)
Carbonates	Ca Mg Cu Zn	Calcite ($CaCO_3$) Dolomite ($CaCO_3.MgCO_3$) Malachite [$CuCO_3.Cu(OH)_2$] Calamine ($ZnCO_3$)
Silicates	Mg, Si Al, Si	Calcium magnesium silicate (asbestos) ($CaSiO_3.MgSiO_3$) China clay ($Al_2O_3.\ SiO_2.\ 2H_2O$)
Sulphides	K, Al, Si Fe Cu Hg Zn Pb	Mica sheets Iron pyrites (FeS_2) Copper pyrites ($CuFeS_2$) Cinnabar (HgS) Zinc sulphide or Zinc blende (ZnS) Lead sulphide, Galena (PbS)
Halides	Na Al K, Mg Ca	Common salt NaCl Cryolite Na_3AlF_6 Carnallite KCl $MgCl_2.6H_2O$ Fluorite CaF_2
Sulphates	Ba Pb Ca	Barytes $BaSO_4$ Anglesite $PbSO_4$ Gypsum $CaSO_4\ .\ 2\ H_2O$

- **Metallurgical operations:** The branch of science which deals with the extraction of metal from its ore is called metallurgy. There is no common process available for the extraction of all the metals because they differ in their chemical and physical properties and

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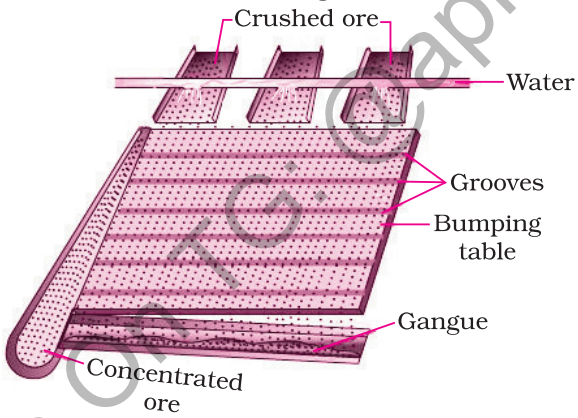
also the impurities associated with them. However, there are certain operations or procedures common in the metallurgy of all metals. These operations or procedures are called Metallurgical Operations. The various steps involved in metallurgical operations are;

1. Crushing and grinding of Ore (Pulverisation)
2. Concentration of ore.
3. Extraction of metal from oxide ore.
4. Refining of crude metal.

- **Mining of ore :** 'Mining' is the process of taking out the ores from the mines. When an ore occurs near the surface of the Earth, it can be directly dug out. Such mining is termed as open pit mining. When an ore is taken out from greater depths then the mining is termed deep mining.
- **Concentration of the ore (ore dressing) :** The removal of the undesired foreign impurities, gangue, from the ore is called concentration (or beneficiation) of the ore. Either of the following methods is used for concentrating the ores :



Wilfley table for the washing of the ore

- **Handpicking :** If the impurities present are quite distinct from the ore, and are of large size, these may be removed by handpicking. This method is slow and is generally adopted in the initial stages of concentration.
- **Gravity or levigation method :** When the ore particles are heavier than the gangue particles, ore is fed into a running stream of water and impurities are washed away. This separation method is commonly used for oxide ores such as haematite and native ore of Au, Ag, etc. In order to concentrate the ore in bulk, a slanting vibrating wooden table with wooden strips called riffles is introduced in the process. Such tables are termed Wilfley tables.
- **Magnetic separation :** It is done, especially in case of hametite ore, whereby the powdered ore is dropped on a leather conveyer belt, which moves over two rollers; one of these rollers is magnetic. When the ore passes over the magnetic roller, it sticks to the belt due to the force of attraction and falls nearer due to the force of

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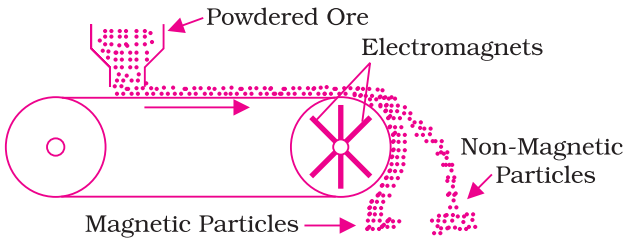
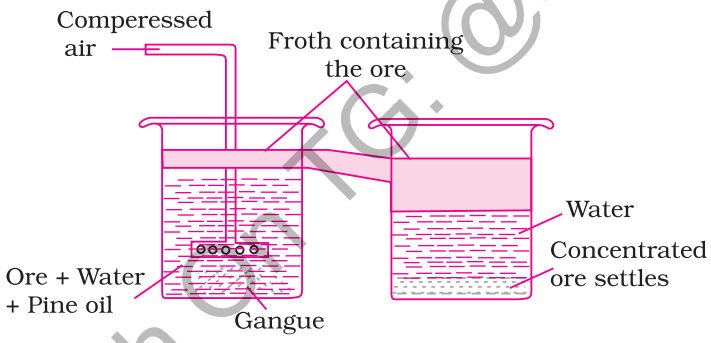
attraction of the magnetized roller. The gangue falls over readily, further away. The ore and the magnetic impurity are collected as two separate heaps.

Magnetic Saperation



- **Froth flotation process :** This process is used for concentrating sulphide ores, as such, ores are entirely wetted by having oil while the gangue particles are wetted by water. Powdered ore is mixed with water and a little pine oil or any other heavy oil. The mixture is then vigorously stirred by passing compressed air. The froth, which is produced, rises to the surface and carries the ore particles along with it. The gangue is left behind at the bottom.



The froth flotation process

- **Leaching process :** In this method, the ore is treated chemically with a suitable reagent that preferentially dissolves the active component of the ore. The concentrated ore formed is then recovered from the solution by a suitable chemical method. A typical example of ore concentration by leaching process is the purification of bauxite using NaOH solution as a leachant.
- **Leaching of bauxite :** Bauxite is digested with the concentrated solution of caustic soda at 150°C in an autoclave. The aluminium oxide dissolves in NaOH leaving behind the insoluble impurities, which are removed by filtration.

$$Al_2O_3.2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O$$

- The solution of $NaAlO_2$ (sodium meta-alumiinate) is then treated with freshly prepared $Al(OH)_3$ when the entire aluminium in the solution gets precipitated as $Al(OH)_3$

$$NaAlO_2 + 2H_2O \rightarrow Al(OH)_3 + NaOH$$

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- The precipitates of $Al(OH)_3$ are removed, washed and dried to get Al_2O_3.
- **Leaching of silver :** Silver is extracted from its ores (argentite, Ag_2S horn silver, AgCl) by cyanide process. The finely powdered concentrated ore is treated with a dilute aqueous solution of NaCN (sodium cyanide) and a current of air is passed through the solution. Silver present in the ore gets dissolved due to the formation of soluble sodium argento-cyanide complex, $Na[Ag(CN)_2]$ viz.,

$$Ag_2S + 4NaCN \rightarrow 2Na[Ag(CN)_2] + Na_2S$$

- Na_2S so formed gets oxidized (by air) to Na_2SO_3, Na_2SO_4 and thus allows the reaction to go in the forward direction. The solution of $Na[Ag(CN)_2)$ is then treated with zinc scrap to recover silver.

$$2Na[Ag(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Ag$$

- With horn silver (AgCl), the reaction with NaCN occurs as,

$$AgCl + 2NaCN \rightarrow Na[Ag(CN)_2] + NaCl$$

Leaching of gold ore

- Gold-containing ore gets dissolved in KCN solution in the presence of air to give a solution containing $K[Au(CN)_2]$. Gold can then be recovered from this solution by either precipitation or electrolytic method.
- Electrostatic concentration and liquation are other methods of the concentrating of ores.
- **Calcination** : The concentrated ore is converted into oxide by calcination, *i.e.* heating it strongly in the absence of air or roasting. This helps remove volatile impurities like CO_2, SO_2, organic matter and moisture from the ore. For example,
  it removes moisture from bauxite.

$$Al_2O_3.2H_2O \xrightarrow{heat} Al_2O_3 + 2H_2O_{(g)}$$

  It removes CO_2 from carbonate ores, e.g.,

$$\underset{\text{Malachite}}{CuCO_3.Cu(OH)_2} \xrightarrow{heat} 2CuO + CO_2(g) + H_2O(g)$$

$$\underset{\text{Dolomite}}{CaCO_3.MgCO_3} \xrightarrow{heat} CaO + MgO + 2CO_2(g)$$

- Calcination is done on the hearth of a reverberatory furnace.
- **Roasting :** It involves the heating of ores mostly sulphide ores strongly, in the presence of excess of air but below its melting temperature. The result is
- It removes moisture, CO_2, SO_2 and organic matter.
- The sulphide ore is converted partly into its oxide or sulphate, *i.e.*

$$PbS + 2O_2 \longrightarrow PbSO_4$$

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_{2(g)}$$

$$ZnS + 2O_2 \longrightarrow ZnSO_4$$

- Roasting is done in a reverberatory furnace or in a blast furnace.

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Smelting :

- **Reduction with carbon :** In this process , the roasted or calcined ore is mixed with suitable quantity of coke or charcoal (which acts as a reducing agent) and is heated to a high temperature above its melting point. During reduction, an additional reagent, is also added to the ore to remove the impurities still present in the ore. The additional reagent added is called flux. Flux combines with the impurities to form a fusible product called slag.

$$\text{Flux} + \text{gangue} \rightarrow \text{Slag}$$

- The selection of flux depends upon the nature of impurities. If the impurities are acidic in nature, the flux is basic, *i.e.* lime (CaO). On the other hand, for basic impurities, an acidic flux, silica (SiO_2) is used.
- The metal oxide , during reduction process, gets reduced to metal.

$$Fe_2O_3 + 3C \rightarrow 2\,Fe + 3CO$$
$$PbO + C \rightarrow Pb + CO$$
$$SnO_2 + 2C \rightarrow Sn + 2CO$$

- The process of reduction with carbon is carried out in the blast furnace.
- **Production of iron from the oxide ore :** The extraction of iron is carried out in a blast furnace. The charge consists of iron ores (haematite, Fe_2O_3 and magnetite, Fe_3O_4), coke or lime stone which is heated with a blast of air. As the exothermic reaction proceeds, a composition and temperature gradient is set up in the furnace. Below 1123 K, CO reduces the ores to FeO. Reduction to Fe by CO can occur at about 1123 K and that direct reduction (in which the reducing agent is C) can occur above 1123 K. In this region, lime stone also decompoes, to give CaO and CO_2 and slag formation takes place. (Slag is the byproduct of iron purification)
- **Reduction with Aluminium :** Certain metal oxides such as Cr_2O_3 and Mn_3O_4 are not easily reduced with carbon. In such cases, aluminium is used as a reducing agent because it is more electropositive than chromium or manganese. The process of the reduction of oxides with aluminium is called aluminiothermy. Some examples are :

$$Cr_2O_3 + 2\,Al \rightarrow Al_2O_3 + 2\,Cr$$
$$3\,Mn_3O_4 + 8\,Al \rightarrow 4\,Al_2O_3 + 9\,Mn$$

- **Reduction with Mg :** In some cases , the reduction is carried out by alkaline earth metals like magnesium.

$$TiCl_4 + 2\,Mg \rightarrow 2\,MgCl_2 + Ti$$

- **Reduction with hydrogen or water gas :** Hydrogen is a very efficient reducing agent. However, its use is limited to those ores where carbon and other reagents are not suitable. It is because of its explosive nature. The roasted ore is heated in small trays in the current of hydrogen gas. For example, tungsten and indium can be obtained by the reduction of their oxides with H_2.

$$WO_3 + 3\,H_2 \rightarrow W + 3\,H_2O$$
$$In_2O_3 + 3\,H_2 \rightarrow 2\,In + 3\,H_2O$$

- Similarly, the extraction of nickel is carried out from its oxide by the use of water gas.

$$2\,NiO + \underbrace{CO + H_2}_{\text{water gas}} \rightarrow 2\,Ni + CO_2 + H_2O$$

- **Electrolytic reduction :** The highly electropositive elements such as alkali metals, alkaline earth metals and aluminium cannot be

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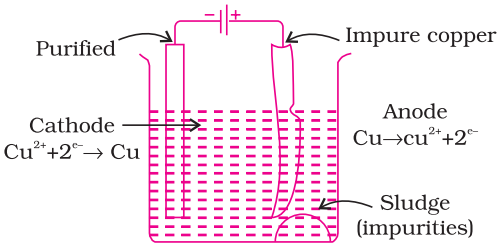
extracted by carbon reduction methods. They are extracted by electrolysis of fused salts. The process of the extraction of metals by the use of electrolysis is called electrometallurgy.



Electrolytic reduction of Copper

- These metals which occur as chlorides or oxosalts are converted into their chlorides. When electric current is passed through a fused chloride, the M^{n+} ions are discharged at the negative electrode (cathode) and deposited. In the electrolysis of brine (NaCl) using mercury cathodes, Na^+ is discharged at the cathode and forms an amalgam. This takes place in preference to the liberation of H_2(expected from electrochemical series) due to high overvoltage at Hg cathode.
- Metals other than the s-block can also be extracted by the electrolysis of fused compounds, e.g. fused Al_2O_3 (Aluminium oxide) mixed with Na_3AlCl_6 (Aluminium Trisodium hexachloride) added to lower the melting point is used for the production of Al.
- This method is widely used in the refining of copper, silver. gold, lead, zinc, aluminium, etc. The impure metal is made the anode and a pure strip of the same metal the cathode in a suitable electrolytic bath. The process takes place as:

  Anode : $M \rightarrow M^{n+} + n\,e^-$

  Cathode : $M^{n+} + n\,e^- \rightarrow M$
- The net result is the transfer of pure metal from anode to cathode. The applied voltage is such that more electropositive metals (impurity) remain as ions in the bath whereas the less electropositive metals(impurities) remain unionised and fall down as anode mud. Thus in the electrolytic refining of copper, more basic metals like zinc remain in the solution as cations, whereas less basic ones like Te, Ag, Au etc go into the anode mud.
- **Cupellation :** This is an oxidation method for the refining of certain metals in which the impurities have greater tendency to get oxidised than the metal itself. Silver is refined by this method. The impure metal is fused in small boat-shaped dishes made of bone ash called *cupels*. The cupels are heated in a suitable furnace by blast of air blown over them. The lead (impurity) is easily oxidised to lead monoxide (PbO) and is carried away by the blast, while pure silver is left behind.
- **Zone refining :** This method is particularly used when metals are required in a high degree of purity. In this method, a metal rod is placed inside a small high frequency induction furnace. A narrow zone of metal is melted. The furnace is slowly moved along the rod.

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The pure metal crystallises out of the melt while impurities remain in the melt which moves along with the melted zone of the rod with the movement of the furnace. The process is repeated several times. The end of the rod where the impurities have collected is cut off. This method is employed for the purification of germanium, silicon, gallium, etc. which are used in semiconductors.

- **Van arkel method :** This method is used for getting ultra pure metals. In this method, the metal is converted to a volatile unstable compound (e.g. iodide) taking care that the impurities are not affected during compound formation. The compound thus obtained is decomposed to get pure metal. This method is used for the purification of metals like titanium and zirconium.
- **Mond process :** Nickel when heated in a stream of carbon monoxide forms volatle nickel carbonyl, $Ni(CO)_4$. The carbonyl vapour, when subjected to still higher temperature, undergoes thermal decomposition giving pure metal.
- **Alloy :** An alloy is the homogenous mixture of two or more metals or of a metal and a non-metal. These alloys are made to prevent corrosion and improve upon the properties of metals as desired for the optimum use.

List of different common alloys in use

Alloy	Components	Typical uses
Alnico	Iron (50%+), aluminium (8–12%), nickel (15–25%), cobalt (5–40%), plus other metals such as copper and titanium.	Magnets in loudspeakers and pickups in electric guitars.
Amalgam	Mercury (45–55%), plus silver, tin, copper, or zinc.	Dental fillings.
Babbitt metal ("white metal")	Tin (90%), antimony (7–15%), copper (4–10%).	Friction-reducing coating in machine bearings.
Brass	Copper (65–90%), zinc (10–35%).	Door locks and bolts, brass musical instruments, central heating pipes.
Bronze	Copper (78–95%), tin (5–22%), plus manganese, phosphorus, aluminium or silicon.	Decorative statues, musical instruments.
Cast iron	Iron (96–98%), carbon (2–4%), plus silicon.	Metal structures such as bridges and heavy-duty cookware.
Cupro-nickel (copper–nickel)	Copper (75%), nickel (25%), plus small amounts of manganese.	Coins.
Duralumin	Aluminium (94%), copper (4.5–5%), magnesium (0.5–1.5%), manganese (0.5–1.5%).	Automobiles and aircraft body parts, military equipment.
Gun metal	Copper (80–90%), tin (3–10%), zinc (2–3%), and phosphorus.	Guns, decorative items.
Magnox	Magnesium, aluminium.	Nuclear reactors.

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Monel	Nickel: 60%, Copper: 33% & Iron: 7%.	Corrosion-resistant containers.
Nichrome	Nickel (80%), chromium (20%).	Firework ignition devices, heating elements in electrical appliances.
Nitinol	Nickel (50–55%), titanium (45–50%).	Shape-memory alloy used in medical items, spectacle frames that spring back to shape, and temperature switches.
Pewter	Tin (80–99%) with copper, lead and antimony.	Ornaments, used for making tableware before glass became more common.
Solder	Varies. Old-fashioned solders contain a mixture of tin (50-70%), lead (30-50%), copper, antimony and other metals. Newer solders dispense with lead for health reasons. A typical modern solder has 99.25 per cent tin and 0.75 per cent copper.	Connecting electrical components into circuits.
Steel (general)	Iron (80–98%), carbon (0.2–2%), plus other metals such as chromium, manganese and vanadium.	Metal structures, car and aeroplane parts, and many other uses.
Steel (stainless)	Iron (50%+), chromium (10–30%), plus smaller amounts of carbon, nickel, manganese, molybdenum and other metals.	Jewellery, medical tools, tableware.
Phosphor bronze	Bronze with a small amount of phosphorus	Springs (normal & electrical) & boat propellers.
Stellite	Cobalt (67%), chromium (28%), tungsten (4%), nickel (1%).	Coating for cutting tools such as saw teeth, lathes and chain saws.
Sterling silver	Silver (92.5%), copper (7.5%).	Cutlery, jewellery, medical equipments, musical instruments.
White gold (18 carat)	Gold (75%), palladium (17%), silver (4%), copper (4%)	Jewellery.
Wood's metal	Bismuth (50%), lead (26.7%), tin (13.3%), cadmium (10%).	Soldering, melting element in fire sprinkler systems
Type metal	Lead (75 – 95%), antimony: 2–18% & tin in trace quantities.	Used for making type characters for printing; also used for making decorative objects like statuettes and candle sticks

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Chapter 17

SOLIDS

Mohs hardness scale, Type of bonds and properties of solids, i.e. ionic, covalent, etc. unit cell, types of unit cell structures, types of crystal systems, defects in solids and their types, i.e. point defects, Schottky and Frenkel defects, line defects, edge and screw dislocations, planar defects, bulk defects squids.

Mohs hardness scale : Hardness is a measure of how easily a material can be scratched. Mohs hardness scale arranges the minerals from 1 to 10. The higher the number, the harder the mineral. Each mineral in the scale will scratch all those below it. Other materials can be compared to these minerals. Copper, for example, has a hardness of 2.5.

Hardness scale in Mohs

Mineral	Hardness in Moh	Mineral	Hardness in Moh
Talc	1	Feldspar	6
Gypsum	2	Quartz	7
Calcite	3	Topaz	8
Fluorite	4	Corundum	9
Apatite	5	Diamond	10

- **Characteristics of solid materials :** There are different types of solids depending on the type of bonds, they have in their atoms or molecules.

Materials with ionic bonds : These

- are hard because particles cannot easily slide past one another.
- are good insulators because there are no free electrons or ions (unless dissolved or melted).
- are transparent because their electrons are not moving from atom to atom and less likely to interact with light photons.
- are brittle and tend to cleave rather than deform because bonds are strong.
- have high melting points and boiling points because ionic bonds are relatively strong.

Materials with Covalent Bonds : These materials

- have low enthalpies of fusion and vapourization.
- can be soft or brittle but good insulators.
- if brittle, are often transparent and cleave rather than deform.

Materials with Metallic Bonds :

- good electrical and thermal conductors due to their free valence electrons
- opaque
- relatively ductile

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Van der Waal Bond

- The van der Waal bonds occur to some extent in all materials but are particularly important in plastics and polymers. The covalent bonds within the molecules are very strong and rupture only under extreme conditions. The bonds between the molecules that allow sliding and rupture to occur are called van der Waal forces.
- The van der Waal forces between molecules increase with increasing density or molecules per unit volume. For example, in polyethylene the molecules are composed of hydrogen and carbon atoms in the same ratio as ethylene gas. But there are more of each type of atom in the polyethylene molecules and as the number of atoms in a molecule increases, the matter passes from a gas to a liquid and finally to a solid.
- In solids, the way the atoms or molecules arrange themselves contributes to the appearance and the properties of the materials.
- **Unit Cells :** The unit cell is the smallest structure that repeats itself by translation through the crystal. Each unit cell is defined in terms of lattice points. Lattice points are points in space about which the particles are free to vibrate in a crystal. We construct these symmetrical units with the hard spheres. The most common types of unit cells are the faced-centered cubic (FCC), the body-centered cubic (FCC) and the hexagonal close-packed (HCP). Other types exist, particularly among minerals. The simple cube (SC) is often used for didactical purpose, no material has this structure.
- **Types of crystal unit cell structures :** There are 14 different types of crystal unit cell structures or lattices found in nature. However, most metals and many other solids have unit cell structures described as body centre cubic (bcc), face- centred cubic (fcc) or hexagonal close-packed (hcp).
- **Body-Centred Cubic (BCC) Structure :** It has atoms at each of the eight corners of a cube (like the cubic unit cell) plus one atom in the centre of the cube. Each of the corner atoms is the corner of another cube, so the corner atoms are shared among eight unit cells. It is said to have a coordination number of 8. The BCC unit cell consists of a net total of two atoms: one in the centre and eight from corner atoms.
- The bcc arrangement does not allow the atoms to pack together so closely as the fcc or hcp arrangements. The bcc structure is often the high temperature form of metals that are closely packed at lower temperatures. The volume of atoms in a cell per the total volume of a cell is called the packing factor. The bcc unit cell has a packing factor of 0.68.
- Some of the materials that have a bcc structure include lithium, sodium, potassium, chromium, barium, vanadium, alpha-iron and tungsten. Metals which have a bcc structure are usually harder and less malleable than close-packed metals such as gold. When the metal is deformed, the planes of atoms must slip over each other, and this is more difficult in the bcc structure.

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- **Face-Centred Cubic (FCC) Structure :** It has atoms located at each of the corners and the centres of all the cubic faces. Each of the corner atoms is the corner of another cube, so the corner atoms are shared among eight unit cells. Additionally, each of its six face-centred atoms is shared with an adjacent atom. Since 12 of its atoms are shared, it is said to have a coordination number of 12. The fcc unit cell consists of a net total of four atoms: eights from corner atoms and six halves of the face atoms.
- In the fcc structure, the atoms are packed closer together than they can in the bcc structure. The atoms from one layer nest themselves in the empty space between the atoms of the adjacent layer. The packing factor is 0.74 for fcc crystals. Some of the metals that have the fcc structure include aluminium, copper, gold, iridium, lead, nickel, platinum and silver.
- **Hexagonal-Close Packed (HCP) Structure :** The hexagonal structure of alternating layers is shifted so that its atoms may be aligned to the gaps of the preceding layer. The atoms from one layer nest themselves in the empty space between the atoms of the adjacent layer just like in the fcc structure. However, instead of being a cubic structure, the pattern is hexagonal.
- The HCP structure has three layers of atoms. In each the top and the bottom layer, there are six atoms that arrange themselves in the shape of a hexagon and a seventh atom that sits in the middle of the hexagon. The middle layer has three atoms nestled in the triangular "grooves" of the top and bottom plane. Note that there are six of these "grooves" surrounding each atom in the hexagonal plane, but only three of them can be filled by atoms.
- The coordination number is 12. There are six nearest neighbours in the same close-packed layer, three in the layer above and three in the layer below. The packing factor is 0.74, which is the same as the fcc unit cell. The hcp structure is very common for elemental metals and some examples include beryllium, cadmium, magnesium, titanium, zinc and zirconium.

Simple cubic (P) Body- centred cubic (I) Face-centred cubic (F)

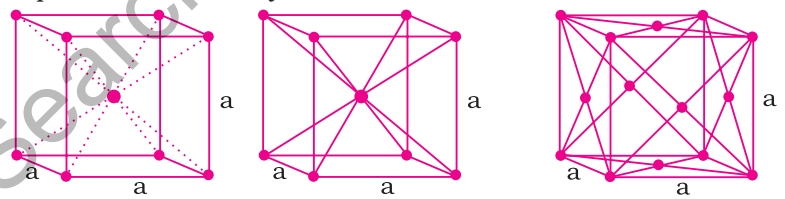

Table showing comparison in different unit cell types

Unit Cell	n	CN	a/R	APF
SC	1	6	2	0.52
BCC	2	8	4Ö 3	0.68
FCC	4	12	2Ö 2	0.74
HCP	6	12	3Ö 6	0.74

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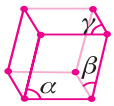
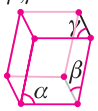
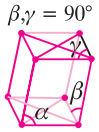
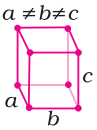
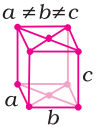
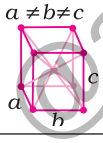
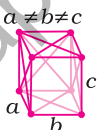
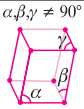
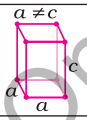
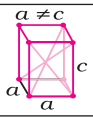
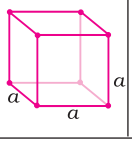
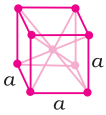
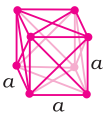
➢ **Crystal systems :** The fourteen space lattice is divided into seven crystal systems. They are triclinic, monoclinic, orthorhombic, tetragonal, trigonal, hexagonal and cubic as shown below in the table with examples.

Lattice Systems	Simple	Base-centered	Body-centered	Face-centered	Example
Triclinic (none)	$\alpha,\beta,\gamma \neq 90°$ 				$CuSO_4.5H_2O$, $K_2Cr_2O_7$
Monoclinic (1diad)	$\alpha \neq 90°$ $\beta,\gamma = 90°$ 	$\alpha \neq 90°$ $\beta,\gamma = 90°$ 			$CaSO_4.2H_2O$, $FeSO_4$, Na_2SO_4
Orthorhombic (3 perpendicular diads)	$a \neq b \neq c$ 	$a \neq b \neq c$ 	$a \neq b \neq c$ 	$a \neq b \neq c$ 	KNO_3, $BaSO_4$
Rhombohedral (1 triad)	$\alpha,\beta,\gamma \neq 90°$ 				As, Sb, Bi
Tetragonal (1 tetrad)	$a \neq c$ 		$a \neq c$ 		TiO_2, SnO_2, $NiSO_4$
Hexagonal (1 hexad)					SiO_2, Zn, Mg, Cd
Cubic (4 triads)					Au, Cu, NaCl

Defects in solids : No solid is perfect, each solid has some kind of defect because imperfections or defect refers to any deviation from the perfect atomic arrangement in a crystal. Crystal imperfections have strong influence upon many properties of crystals, such as:

➢ Strength, electrical conductivity and hysteresis loss of ferromagnets.

➢ Conductivity of some semi-conductors is due entirely to the trace amount of chemical impurities.

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- Colour, luminescence of many crystals arise from impurities and imperfections. Such as in diamond with C vacancies (missing carbon atoms) absorbs light, and these centres give green colour. The replacement of Al^{3+} for Si^{4+} in quartz gives rise to the colour of smoky quartz.
- Atomic diffusion may be accelerated enormously by impurities or imperfections.
- Mechnical and plastic properties are usually controlled by imperfections.
- Imperfections in crystalline solids are normally classified according to their dimensions as follows :
- **Point defects and line defects Imperfections or defects :** Point defects are defects that occur only at or around a single lattice point. Point defects seen in AgBr, AgI, RbAgI include self-interstitial atoms, interstitial impurity atoms, substitutional atoms and vacancies.
- **A self interstitial atom** is an extra atom that has crowded its way into an interstitial void (empty space) in the crystal structure. Self interstitial atoms occur only in low concentrations in metals because they distort and highly stress the tightly packed lattice structure.
- **A substitutional impurity atom** is an atom of a different type than the bulk atoms, which has replaced one of the bulk atoms in the lattice. An example of substitutional impurity atoms is the zinc atoms in brass.
- **Interstitial impurity atoms** are much smaller than the atoms in the bulk matrix. Interstitial impurity atoms fit into the open space between the bulk atoms of the lattice structure, e.g., the carbon atoms added to iron to make steel.

Schottky imperfection v/s Frenkel imperfection	
Due to equal number of cations and anions missing from lattice site.	Due to the missing of ions from lattice site but their movement to interstitial site.
Commonly found in highly ionic compounds, e.g., CsCl, NaCl, etc.	Commonly found in solids having cations and anions with large difference in size, e.g., ZnS, AgCl
It leads to decrease in the density with missing ions.	It has no effect on density.

- **Line Imperfections :** In linear defects, commonly called dislocations, groups of atoms are in irregular positions. Any deviation from perfectly periodic arrangement of atoms along a line is called the line imperfection. In this case, the distortion is centred only along a line and, therefore, the imperfection can be

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considered as the boundary between the two regions of a surface which are perfect themselves but are out of register with each other. The line imperfection acting as boundary between the slipped and un-slipped region, lies in the slip plane and is called a dislocation. Dislocations are generated and move when a stress is applied. The strength and ductility of metals are controlled by dislocations.

- **Edge Dislocations :** These occur when inter-atomic bonds are significantly distorted only in the immediate vicinity of the dislocation line. The dislocation moves a small amount at a time. The dislocation in the top half of the crystal slips one plane at a time as it moves to the right from its position. In the process of slipping one plane at a time, the dislocation propagates across the crystal. The movement of the dislocation across the plane eventually causes the top half of the crystal to move with respect to the bottom half. However, only a small fraction of the bonds is broken at any given time.
- **Screw Dislocations :** In this, the motion is a result of shear stress, but the defect line movement is perpendicular to the direction of the stress. In the edge dislocation, movement requires a much smaller force than breaking all the bonds across the middle plane simultaneously. If the shear force is increased, the atoms will continue to slip to the right.
- **Planar defects :** These are interfaces between the homogeneous regions of the material. Planar defects include grain boundaries, stacking faults and external surfaces.
- **Stacking Faults and Twin Boundaries :** A disruption of the long-range stacking sequence can produce two other common types of crystal defects: 1) a stacking fault and 2) a twin region. A change in the stacking sequence over a few atomic spacings produces a stacking fault whereas a change over many atomic spacings produces a twin region. A stacking fault is a one or two-layer interruption in the stacking sequence of atom planes. Stacking faults occur in a number of crystal structures. The face centered cubic (fcc) structures differ from hexagonal close-packed (hcp) structures only in their stacking order. For hcp and fcc structures, the first two layers arrange themselves identically, and are said to have an AB arrangement. If the third layer is placed so that its atoms are directly above those of the first (A) layer, the stacking will be ABA. This is the hcp structure, and it continues as ABABABAB. However, it is possible for the third layer atoms to arrange themselves such that they are in line with the first layer to produce an ABC arrangement which is of the fcc structure. So, if

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the hcp structure is going along as ABABAB and suddenly switches to ABABABCABAB, there is a stacking fault present.

- **Grain Boundaries in Polycrystals**: It is another type of planar defect as solids generally consist of a number of crystallites or grains. Grains can range in size from nanometres to millimetres across and their orientations are usually rotated with respect to neighbouring grains. Where one grain stops and another begins is known as a grain boundary. Grain boundaries limit the lengths and motions of dislocations. Therefore, having smaller grains (more grain boundary surface area) strengthens a material. The size of the grains can be controlled by the cooling rate. Generally, rapid cooling produces smaller grains whereas slow cooling results in larger grains.
- **Volume or Bulk Defects :** These defects occur on a much bigger scale than the rest of the crystal defects . They affect the movement of dislocations. Voids are regions where there are a large number of atoms missing from the lattice. These voids can occur due to air bubbles becoming trapped when a material solidifies it is commonly called porosity. When a void occurs due to the shrinkage of a material as it solidifies, it is called cavitation.
- Another type of bulk defect occurs when impurity atoms cluster together to form small regions of a different phase. The term 'phase' refers to that region of space occupied by a physically homogeneous material. These regions are often called precipitates or inclusions.
- Some types of glass are made by mixing silica (SiO_2), alumina (Al_2O_3), calcium oxide (CaO) and sodium oxide (Na_2O) because of the presence of voids in glass. These are softer and due to lower melting points, they are easy and cheaper to be produced by manufacturers.

Charactristics of metal excess defects.

Metals having metal excess defects are :

— good conductor of electricity upto certain limit.

— generally coloured because of presence of free electrons.

- SQUIDS : These are Superconducting Quantam Interference Devices which are very sensitive to change in magnetic field and measure voltage as small as 10^{-18}V and also current as small as 10^{-18}A. Hence, these devices are widely being used in medical science to detect small changes in magnatic field occuring in human brain. The geologists use these divices to detect the pressure of a magnetic field caused by the presence of over in earth crust.

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Chapter 18

SOLUTIONS

CHEMISTRY

Properties of a solution, colloid, suspension, the solution properties, solubility, degree of saturation, super saturated solution, concentrated and dilute solution, molality, dilution, mass percent of solution, electrolytes and their types, colligative properties, depression in freezing point and elevation in boiling point.

- **Properties of Solutions :** A solution is a homogenous mixture of two or more substances that exist in a single phase. There are two main parts to any solution: solute and solvent. The solute is the component of a solution that is dissolved in the solvent, it is usually present in a smaller amount than the solvent. The solvent is the component into which the solute is dissolved, and it is usually present in greater concentration.
- In solutions where water is the solvent, the solution is referred to as an aqueous solution.
- A solution is formed when polar, ionic substances dissolve in polar solvents, while non-polar solutes dissolve in non-polar solvents. For example, alcohol and water, which are both polar, can form a solution and iodine and carbon tetrachloride, which are both non-polar, make a solution. However, iodine will not readily dissolve in polar water.
- In a solution, the particles are really small—anywhere from 0 to 100 nm. They never settle on standing they cannot be separated by filtering, and light will pass through a solution unchanged.

Classification of solutions :

Types of solutions	Examples
Solution of gas in gas	Air, mixture of gases.
Solution of liquid in gas	Solution of gases like Br, CO_2, NH_3, etc. in water, cloud, mist, fog, etc.
Solution of solid in gas	Solution of iodine in air, smoke, etc.
Solution of gas in liquid	Solution of CO_2 in water (H_2O), Solution of HCl gas in benzene (C_6H_6), etc.
Solution of solid in liquid	Solution of alcohol in water, solution of bromine in alcohol, soluion of H_2SO_4 in water, etc.
Solution of solid in liquid	Solution of sugar in water, solution of iodine in carbon tetrachloride, solution of lead in mercury, starch, gel, protein, etc.
Solution of liquid in solid	Solution of mercury in thalium, solution of water in sugar, solution of water in salt, etc.
Solution of solid in solid	Zinc in copper, aluminium in copper, solution (alloys) of zinc and nickel in copper.

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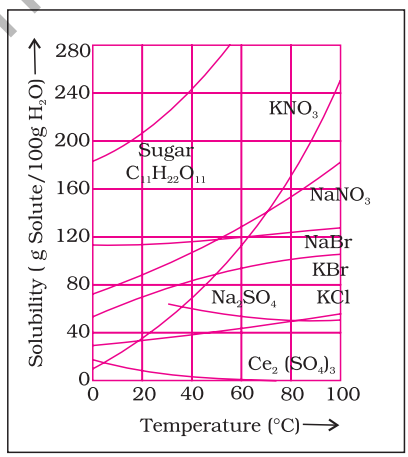
- **Colloid :** One type of mixture that is not a solution is colloid. In a colloid, particles are between 100 and 1000 nm in size still too small for our eyes to distinguish, also particles of this smallness will not settle. As is the case in solutions, the particles cannot be filtered, but they do scatter light. Some examples of colloids include gelatin, fog, smoke and shaving cream.
- Suspensions have much larger particles, usually over 1000 nm. Particles in a suspension will settle on standing, can often be separated by a filter, and may scatter light, but they are usually not transparent. Some examples of suspensions are muddy water, paint and some medicines, like Pepto-Bismol.
- **The Solution Process :** In order for a solute to be dissolved in a solvent, the attractive forces between the solute and solvent particles must be great enough to overcome the attractive forces within the pure solvent and pure solute. The solute and solvent molecules in a solution are expanded compared to their position within the pure substances.
- The process of expansion, for both the solute and the solvent, involves a change in the energy of the system: this process can be either exothermic or endothermic. After dissolving, the solute is said to be fully solvated (usually by dipole-dipole or ion-dipole forces), and when the solvent is water, the solute is said to be hydrated. The separation of the solute particles from one another prior to dissolving is an endothermic process for both the solvent and solute but when the solute and solvent combine with each other, this is an exothermic process. If the energy released is greater than the energy absorbed, the solution is formed and stable.
- **Solubility :** It refers to the maximum amount of material that will dissolve in a given amount of solvent at a given temperature to produce a stable solution. By looking at the plot of solubilities below, it becomes clear that solubility of most solids increase with an increase in temperature.

  However, in gases the solubility decreases with increase in temperature as gaseous molecules escape from the mixture.



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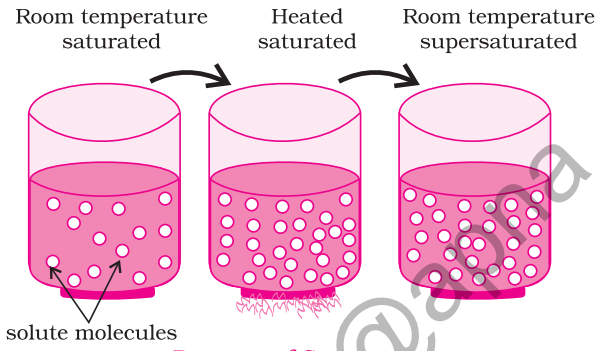
Degrees of Saturation

- While referring to solutions, there are three degrees of saturation. They are unsaturated, saturated and supersaturated. If a solution is un- saturated, the solvent is capable of dissolving more solute. When the solution is saturated, the solvent has dissolved the maximum amount of solute that it can at the given temperature. At this point, we say that the solution is in a state of dynamic equilibrium –the processes of dissolving and precipitation happen at the same rate.



Degrees of Saturation

- **Supersaturated solution :** It is one in which the solvent contains more solute than it can theoretically hold at a given temperature. Supersaturated solutions are often formed by heating a solution and dissolving more solute, then cooling the solution down slowly. These solutions are unstable and crystallize readily.
- **Concentration Terms :** Solutions are often referred to as being concentrated or dilute. These two terms are very general. While concentrated indicates that there is a lot of solute dissolved in the solvent (perhaps the solution is near to being saturated) and dilute indicates that a small amount of solute is dissolved in the solvent; we often need to be exact with quantities in chemistry.
- **Molarity (M) :** The molarity of a solution is a measure of the number of moles of solute per litre of solution. This is the most common concentration unit used in chemistry.

$$M = \frac{\text{moles of solute}}{\text{litres of solution}}$$

- **Problem :** Calculate the molarity of a solution prepared by dissolving 20.0 g of solid NaOH in enough water to make 100 mL of solution.

Solution : Convert grams to moles:

$$\frac{20.0\text{g NaOH}}{40.0\text{g / mol NaOH}} = 0.500 \text{ mol NaOH}$$

Then convert mL to litres:

$$\frac{100 \text{ mL}}{1000\text{mL / L}} = 0.100 \text{ L solution, now dividing the above two}$$

$$\frac{0.500\text{mol}}{0.100\text{ L}} = 5.00 \text{ M NaOH}$$

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- **Dilution :** It is the process of taking a more concentrated solution and adding water to make it less concentrated. A concentrated solution before the dilution performed is known as the stock solution. The concentration of the stock solution to the concentration of the diluted solution is related using the equation below:

$$M_1V_1 = M_2V_2$$

where M is molarity and V is the volume, in litres, of the solution.

- **Problem :** What volume of 6.0 M sulphuric acid (H_2SO_4) must be used for preparing 2.0 L of a 0.10M H_2SO_4 solution?

Solution : Just substitute the numbers into the formula.

Here, $M_1 = 6.0M$; $V_1 = ?$

$M_2 = 0.10M$; $V_2 = 2.0L$

$M_1V_1 = M_2V_2$

$(6.0\ M)\ (V_1) = (0.10\ M)\ (2.0\ L)$

$V_1 = 0.033\ L$

or 33 mL should be measured out and then diluted by adding enough water to make 2.00 L total volume.

- **Mass Per cent (Weight Per cent) :** It is another way of expressing the concentration of a solution. It is found by dividing the mass of the solute by the mass of the solution and multiplying by 100.

$$\text{Pass percent} = \frac{\text{grams of solute}}{\text{g of solute} + \text{g of solvent}} \times 100$$

- **Problem :** A solution is prepared by mixing 5.00g ethanol (C_2H_5OH) with 100.0 g water. Calculate the mass percent of ethanol in this solution.

Solution : Substituting the values, we are given, into the mass percent equation:

grams of solute = 5.00g; grams of solvent = 100.0g

$$\% = \frac{5.00\,g}{100\,g + 5.00\,g} \times 100 = 4.76\% \text{ ethanol}$$

- **Molality (m) :** The **molality** of a solution is a measure of the number of moles of solute per kilogram of solvent. Whereas the *molarity* of a solution is dependent on the volume of the solution, the *molality* is dependent on the mass of the solvent in the solution.

$$m = \frac{\text{moles of solute}}{\text{kilograms of solvent}}$$

- **Problem :** A solution is prepared by mixing 80.0 g of sodium hydroxide (NaOH) with 500.0 g of water. Calculate the molality of this solution.

Solution : Convert grams of solute to moles:

$$\frac{80.0\,g\ NaOH}{40.0\,g\ /\ mol\ NaOH} = 2.00\ mol$$

Convert grams of solvent to kg: $\frac{500.0\ g}{1000g\ /\ kg} = 500\ kg$

Divide: $\frac{2.00\ mol\ NaOH}{0.500} = 4.00\ m$

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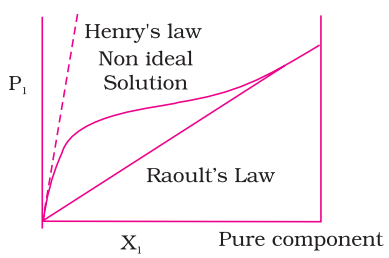
- **Electrolytes :** Certain solutions are capable of conducting an electric current and these solutions are referred to as electrolytes. There are three classes of electrolytes (solutions that conduct a current): acids, bases and salts.
- Strong electrolytes consist of solutes that dissociate completely in a solution. Strong acids, strong bases and soluble salts are in this category.
- Non electrolytes are substances that are predominantly covalently bonded, generally will not produce ions in solution and, therefore, are considered non-conductors.
- Weak electrolytes consist of solutes that dissociate only a little in a solution. Weak acids, weak bases and slightly soluble salts are in this category.
- The greater the degree of dissociation of the solute, the greater the conductivity of the solution.
- **Colligative Properties :** The properties of solutions which depend on the number of solute particles present per solvent molecule are called colligative properties such as the concentration of solute in a solution can affect various physical properties of the solvent including its freezing point, boiling point and vapour pressure.
- **Ideal vs. Non-ideal Solutions :** Raoult's Law only works for ideal solutions. An ideal solution shows thermodynamic mixing characteristics identical to those of ideal gas mixtures [except]; ideal solutions have intermolecular interactions equal to those of the pure components. However, it still works fairly well for the solvent in dilute solutions. However, in reality the decrease in vapour pressure will be greater than that calculated by Raoult's Law for extremely dilute solutions.
- *Positive non-ideal behaviour of the vapour pressure of a solution follows* Henry's Law *at low concentrations and Raoult's law at high concentrations (pure).*
- **Raoult's Law :** It states that for an ideal solution the partial vapour pressure of a component in solution is equal to the mole fraction of that component times its vapour pressure when pure:

$$P_a = X_a P_a^o$$



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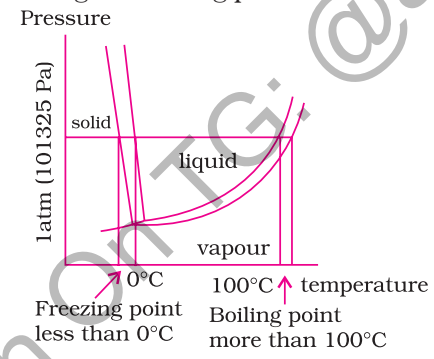
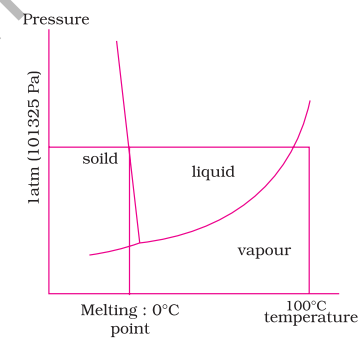
- Where P_a = vapour pressure of the solution, P_a° = vapour pressure of pure solvent and X_a = mole fraction of the solvent
- The fractional vapour pressure lowering is equal to the mole fraction of the solute: $X_b = (P_a^\circ - P_a) \div P_a^\circ$
- Where P_a = vapour pressure of the solution , P_a° = vapour pressure of pure solvent and X_b = mole fraction of the solute.
- Fractional vapour pressure lowering can be used for calculating molecular mass (formula weight) of a solute.

Raoult's Law and Colligative Properties

- The effect of Raoult's Law is that the saturated vapour pressure of a solution is going to be lower than that of the pure solvent at any particular temperature. It has important effects on the phase diagram of the solvent. The next diagram shows the phase diagram for pure water in the region around its normal melting and boiling points. The atmosphere line shows the conditions for measuring the normal melting and boiling points.





Phase diagram of a pure solvent

- **Freezing Point Depression :** The freezing point of a substance is defined as the temperature at which the vapour pressure of the

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solid and the liquid states of that substance are equal. If the vapour pressure of the liquid is lowered, the freezing point decreases. In a solution. Freezing point can be depressed below that of a pure solvent because molecules cluster in order to freeze. They must be attracted to one another and have a spot of where to cluster; if they act as a solvent, solute molecules get in the way and prevent them from clustering tightly together. The more ions in solution, the greater the effect on the freezing point. We can calculate the effect of these solute particles by using the following formula : $DT_f = K_f \times m_{solute}\, i$

- Where DT_f = the change in freezing point, K_f = molal freezing point depression constant for the substance (for water = 1.86°C/m), m = molality of the solution and ni = number of ions in solution (this is equal to 1 for covalent compounds and is equal to the number of ions in solution for ionic compounds)
- **Boiling Point Elevation :** The boiling point of a substance is the temperature at which the vapour pressure equals atmospheric pressure. Because vapour pressure is lowered by the addition of a non-volatile solute, the boiling point is increased because the solute particles get in the way of the solvent particles trying to escape the substance as they move around faster, it will take more energy for the vapour pressure to reach atmospheric pressure, and thus the boiling point increases. One can calculate the change in boiling point in a way that's similar to how we calculate the change in freezing point : $DT_b = K_b m_{solute} i$
- Where K_b = molal boiling point elevation constant (for water = 0.51°C/m),
- **Problem :** Calculate the freezing point and boiling point of a solution of 100 g of ethylene glycol ($C_2H_6O_2$) in 900 g of water.

Solution : First calculate molality :

$$100 \text{ g ethylene glycol} \times \frac{1 \text{ mol ethylene glycol}}{62.0\text{g ethylene glycol}}$$

$$m = \frac{1.61 \text{ mol}}{0.900\text{kg}} = 1.79 \text{ m}$$

- Freezing point depression = $(m)(K_f)(i)$
- T_f = (1.79)(1.86)(1) = 3.33°C
- Freezing point = 0°C - 3.33°C = -3.33°C
- Boiling point elevation = $(m)(K_{mt})(i)$
- T_b = (1.79)(0.51)(1) = 0.91°C
- Boiling point = 100°C + 0.91°C = 100.91°

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Chapter 19

ELECTROCHEMISTRY

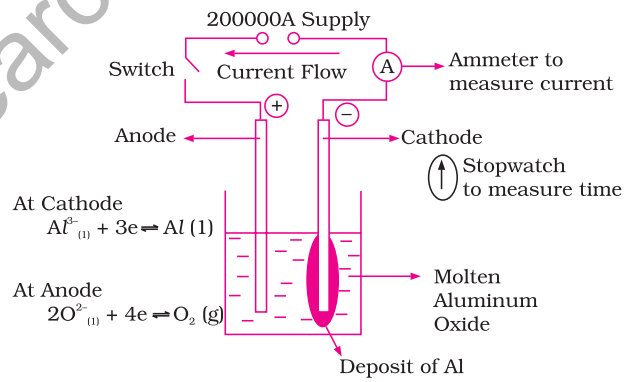
Electrolysis, electrochemical v/s electrolytic cell, Faraday's laws of electrolysis, resistance, conductance, specific resistivity, equivalent conductivity, molar conductivity, Kohlrausch law, standard electrode potential, electrochemical series, dry cell, mercury cell, lead storage battery, nickel-cadmium cell, fuel cell and corrosion, i.e. rusting of iron as an electrochemical process.

- **Electrolysis :** It is the process of the decomposition of an electrolyte by the passage of electricity through its aqueous solution or molten state.

Electrolytic cell v/s electrochemical cell

Electrochemical cell	Electrolytic cell
It converts chemical energy into electrical energy.	It converts electrical energy into chemical energy.
The redox reaction is spontaneous and is responsible for the production of electrical energy.	The redox reaction is not spontaneous, the electrical energy needs to be supplied to initiate the reaction.
The two half cells are set up in different containers.	Both the electrodes have to be placed in the same container immersed in molten electrolyte.
In these cells, anode is negative and cathode is positive electrode.	In these cells, anode is positive and cathode is negative electrode.
The electrons are supplied by the species getting oxidized.	The electrons are supplied by an external battery.

- **Faraday's first law of electrolysis :** In a chemical reaction, the amount of any substance deposited or liberated is directly proportional to the quantity of electricity passed through it.



Faraday's Ist law

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$W \alpha Q$

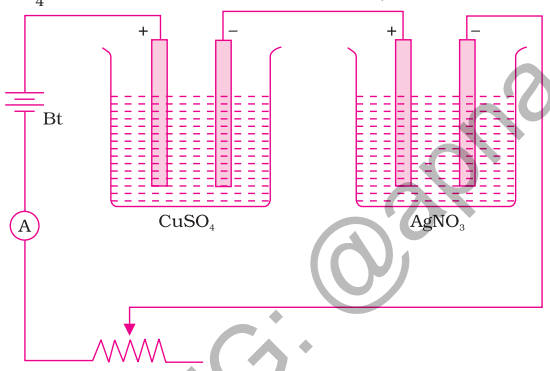
$W = ZQ$

$W = Zit$ $(Q = It)$

Where, Z = Electrochemical Equivalent.

Z = atomic weight/nF ; (n = no. of electron, F = 96500)

➢ **Faraday's second law of electrolysis :** When the same quantity of electricity is passed through the different electrolytes connected in series. The weights of the substance produced at the electrodes are directly proportional to their equivalent weights, e.g., if $AgNO_2$ and $CuSO_4$ solution connected in series,



$$\frac{\text{weight of Ag deposited}}{\text{weight of Cu deposited}} = \frac{\text{Eq.Wt. of Ag}}{\text{Eq.Wt. of Cu}}$$

Faraday's 2nd law

Conductance of electrolytic solution : Electrolytes conduct electricity by decomposition.

➢ **Electrical resistance :** The electrical resistance of an electrical conductor is a measure of the difficulty, an electric current has to face when passing through a conductor. If voltage v is applied to the ends of the conductor and current I flow through it, then the resistance "R" of the conductor is V/I.

V= IR S.I. Unit Ef 'R' is Ohm (Ω)

➢ **Electrical conductance:** The reciprEcal Ef electrical resistance is called cEnductance, and is represented by G sign

Thus, G = 1/R [unit Ef G = mhE]

Specific resistance Er Resistivity:- it is Ebserved that,

$$R \alpha l \text{ Er, } R \alpha \frac{l}{a} \text{ Er, } R = \rho \frac{l}{a}$$

There ρ is cEnstant and called as **resistivity.**

➢ **Specific conductance or conductivity:-**The reciprEcal Ef resistivity is knEwn as cEnductivity. It is denEted by k (kappa).

R = 1/G Er, ρ = 1/K .....(i)

As we knEw, R = π 1/a .....(ii)

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From equation (i) and (ii)
We get,

$$\frac{1}{G} = \frac{1}{K} \times \frac{1}{a} \text{ or } = G \times \frac{1}{a}$$

Electrical conductance is measured in siemens (s).

- **Equivalent conductivity :** Equivalent conductivity of a solution at a dilution v is defined as the conductance of all the ions produced from one gram equivalent of the electrolyte dissolved in v cm^3 of the solution when the distance between the electrode is one cm and the area of the electrode is so large then the whole solution comes between them.
  It is represented by Λ_{eq} (Lamda)
  Equivalent conductivity = Specific conductivity × V
  $$\Lambda_{eq} = K \times V$$
  Or $\Lambda_{eq} = K \times 1000/C_{eq}$
  Where C_{eq} is the concentration of solution in gm eq/L.
- **Specific conductivity, K :** $K = G \times 1/a$
- Where 1/a is constant called cell constant and is represented by G'
  Therefore, $K = G \times G'$
  Molar conductivity (Λ) : $\Lambda_m = K \times 1000/c$
  Where c is the molar concentration of the electrolyte.
- **Kohlrausch's law :** The law states that the limiting molar conductivity of an electrolyte (*i.e.* molar conductivity at infinite dilution) is the sum of the limiting ionic conductivities of the cation and the anion each multiplied with the number of ions present in one formula unit of the electrolyte, *i.e.*
  $$\Lambda^\circ_m \text{ for } A_xB_y = x\lambda^\circ_{(A)}y^+ + y\lambda^\circ_{(B)}x^-$$
- Where, Λ°_m is the limiting molar conductivity of the electrolyte $\lambda^\circ_{(A)}y^+$ and $y\lambda^\circ_{(B)}x^-$ are the limiting conductivities of the cation and anion respectively.
- **Kohlrausch's law in terms of equivalent conductivity**: The equivalent conductivity of an electrolyte at infinite dilution is the sum of two values; one depends upon cation and other upon anion.
  $$\Lambda^\circ_{eq} = \lambda^\circ_c + \lambda^\circ_a$$
  Where, λ°_c and λ°_a are the limiting ionic conductivities of the cation and anion respectively.
- **Electrode Potential :** The electrical potential difference set up between metals and its ions in the solution is called electrode potential. Electrode potential is also called as the electromotive force (e.m.f.) of a cell consisting of two electrodes.
- **Cell potential or EMF of a cell :** The difference between the electrode potential of the two half cells is known as cell potential or cell voltage; it is called Electromotive Force or EMF of the cell if no current is drawn from the cell.
- **Electrochemical series**: The larger the value of the standard reduction potentials, the easier it is for the element to be reduced

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(accepted electrons); in other words, they are better oxidizing agents. The various electrodes have been arranged in order of their increasing value of standard reduction potentials. This arrangement is called electrochemical series.

Equilibrium	E° (volts)
$Li^{+}_{(aq)} + e^{-} \rightleftharpoons Li_{(s)}$	-3.03
$k^{+}_{(aq)} + e^{-} \rightleftharpoons K_{(s)}$	-2.92
$Ca^{2}_{(aq)} + 2e^{-} \rightleftharpoons Ca_{(s)}$	-2.87
$La^{2}_{(aq)} + 2e^{-} \rightleftharpoons Ca_{(s)}$	-2.71
$Mg^{2}_{(aq)} + 2e^{-} \rightleftharpoons Mg_{(s)}$	-2.37
$Al^{3}_{(aq)} + 3e^{-} \rightleftharpoons Al_{(s)}$	-1.66
$Zn^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Zn_{(s)}$	-0.76
$Fe^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Fe_{(s)}$	-0.44
$Pb^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Pb_{(s)}$	-0.13
$2H^{+}_{(aq)} + 2e^{-} \rightleftharpoons H_{2(s)}$	0
$Cu^{2}_{(aq)} + 2e^{-} \rightleftharpoons Cu_{(s)}$	+0.34
$AG^{+}_{(aq)} + e^{-} \rightleftharpoons Ag_{(s)}$	+0.80
$Au^{3}_{(aq)} + 3e^{-} \rightleftharpoons Au_{(s)}$	+1.50

Nernst equation for electrode potential:

$$M^{n+} + ne^{-} \rightarrow M$$

Then Nernst equation is,

$$E = E^{\circ} - \frac{RT}{nF} \ln \frac{[M]}{[M^{n+}]}$$

Where, E = electrode potential under the given concentration of M^{n+} ions and temperature T.

E^{0} = standard electrode potential, R = gas constant, T = Temperature in K, F = one Faraday and n = No. of electrons involved in the electrode reaction.

Also put, R = 8.314 $Jk^{-1}mol^{-1}$, F = 96500 coulombs and T = 298 k

we get, E = $E = E^{\circ} - \frac{0.0591}{n} \log \frac{1}{[M^{n+}]}$

- **Primary Cells :** The cells which cannot be recharged are called primary cells.
- **Dry cell :** It consist of a cylindrical zinc container which acts as an anode. A graphite rod is placed between the centre, acts as a cathode. The space between the cathode and the anode is so packed with the paste of NH_4Cl and $ZnCl_2$ and graphite is surrounded by MnO_2 and carbon.

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Cell reaction, *At Anode*: $Zn\ (s) \rightarrow Zn^{2+}\ (aq) + 2^{e-}$

At cathode : $2MnO_2\ (s) + 2NH_4^+\ (aq) + 2e^- \rightarrow Mn_2O_3\ (s) + 2NH_3\ (g) + H_2O$

These cells with voltage in the range of 1.25 V to 1.50 V do not have long life.

- **Mercury cell (Ruber Mallory cell) :** It consists of a zinc container as anode, a carbon rod as cathode and a paste of mercuric oxide mixed with KOH as the electrolyte. A lining of porous paper separates the electrolyte from the zinc container.

  Cell reaction : *At Anode* : $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

  At Cathode : $HgO + H_2O + 2e^- \rightarrow Hg + 2OH^-$
- **Secondary cell :** The cells which can be recharged are called secondary cells. In these cells energy can be renewed by passing a current in the direction opposite to that of the flow of current generated by the cell.
- **Lead storage battery :** The cell consists of lead anode and a grid of lead packed with lead dioxide acts as lead cathode. These electrodes are arranged alternatively separated by a fibre glass sheet and suspended in sulphuric acid (H_2SO_4) (dilute) which acts as an electrolyte.
- An electrode reaction occurs during discharge battery:

  At anode: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$ because $Pb \rightarrow Pb^{2+} + 2^{e-}$

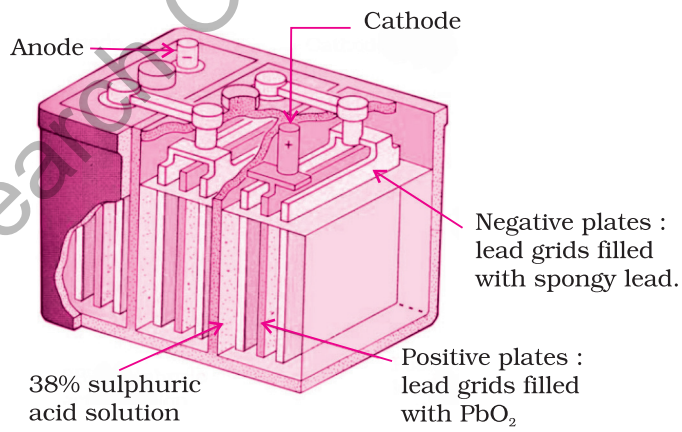
  At cathode : $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$

  In above reactions, H_2SO_4 is used, hence, the density of H_2SO_4 decreases when battery discharges.

  During charging : The electrode reaction is reserved.

  $PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$

  $PbSO_4 + 2H_2O \rightarrow PbO_2 + SO_4^{2-} + 4H^+ + 2e^-$



- **Nickel Cadmium Storage Cell :** It consists of cadmium electrode (as Anode) and metal grid of nickel oxide as cathode immersed in KOH solution.

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Reaction occurs during the discharge of cell:

At Anode : $Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$

At Cathode : $NiO_2 + 2H_2O + 2e^- \rightarrow Ni(OH)_2 + 2OH^-$

- Hence, the reaction can be reversed during charging. The potential of each Ni-Cd cell is approximately 1.4 V:

$$2Ni(OH)_3 + Cd \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} 2Ni(OH)_2 + Cd(OH)_2$$

- **Fuel cell :** It consists of porous carbon electrodes containing suitable catalyst incorporated in them. Concentrated KOH or NaOH solution is placed between the electrodes to act as the electrolyte. The hydrogen or oxygen gases are bubbled through the porous electrode into the KOH/NaOH solution.

  Reactions : *At Anode*: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$

  At Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

- **Corrosion :** The process of slowly eating or wasting away of metal due to the attack of atmospheric gases on the surface of metal resulting into the formation of compounds such as oxides, sulphides, carbonates, sulphates, etc. is called as corrosion.
- In corrosion, the metal is oxidized by the loss of electrons to oxygen and formation of oxides. The corrosion of iron occurs in the presence of air & water. Iron sheet or object behaves like a surface where oxidation takes place.

  Anode : $2Fe(s) \rightarrow 2Fe^{2+} + 4e^-$ and these electrons move to another spot where reduction takes place in the presence of H^+ ion (H_2CO_3)

  At cathode : $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

  The overall reaction being $2Fe + O_2 + 4H^+ \rightarrow 2Fe^{2+} + 2H_2O$

  $E^0_{(cell)} = 1.67$ v

  Fe^{2+} (ferrous ion) oxidised by O_2 to form ferric ion (Fe^{3+}) which comes out as rust $Fe_2O_3.xH_2O$.

- Silver corrodes with the formation of blackish sulphide layer on the surface.

$$2Ag + H_2S \rightarrow Ag_2S + H_2$$

- Copper corrodes depositing a greenish layer exposed to moisture and carbon dioxide.

$$Cu + H_2O + CO_2 \rightarrow Cu(OH)_2 + CuCO_3 \text{ (Greenish coating)}$$

- Strategic metals such as gold, platinum, also called white gold, stontium, etc., do not corrode easily. Hence, they are also sometimes considered as noble metals.

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Chapter 20

CHEMICAL KINETICS

Chemical kinetics, factors affecting rate of a reaction, exothermic and endothermic reactions, catalysts and their characteristics, rate law, order of reaction, zeroth order, first order, second order and third order reactions and half life of reactions.

- **Chemical kinetics :** It refers to the study of chemical reactions with respect to *reaction rates, effect of various variables, re-arrangement of atoms, formation of intermediates, etc.*

At the macroscopic level, chemistry deals with reactant(s) amounts reacted, product(s) formed, and the rates of their formation. At the molecular or microscopic level, chemistry deals with the study of chemical reaction mechanism. It means:

- Molecules or atoms of reactants must collide with one another in chemical reactions.
- The colliding (atoms) molecules must have sufficient energy called activation energy to collide with to initiate the reaction.
- The proper orientation of the molecules during the collision, if necessary.
- **Reaction Rates :** Chemical reaction rates are the rates of change in concentrations or amounts of either reactants consumed or products produced during the course of reaction in a unit time. For changes in amounts, the units can be one of mol/s, g/s, lb/s, kg/day etc. For changes in concentrations, the units can be one of mol/(L s), g/(L s), %/s, etc.
- With respect to reaction rates,one may look into average rates, instantaneous rates or initial rates depending on the experimental conditions.

Thermodynamics and kinetics are two factors that affect the reaction rates.

- **Thermodynamics :** It refers to the study of energy gained or released in chemical reactions and such collected energy data is called thermodynamic data. However, thermodynamic data have no direct correlation with reaction rates, for which the kinetic factor is perhaps more important. For example, at room temperature (a wide range of temperatures), thermodynamic data indicates that diamond shall convert to graphite, but in reality, the conversion rate is so slow that most people think that diamond is forever.
- **Factors Influence Reaction Rates :** Many factors influence rates of chemical reactions, and these are summarized below.

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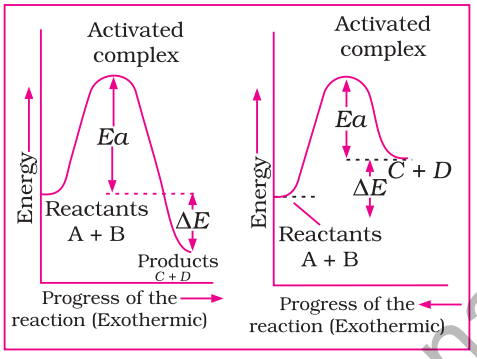
- **Nature of Reactants :** Acid-base reactions, formation of salts, and exchange of ions are fast reactions. Reactions in which large molecules are formed or break apart are usually slow. Reactions breaking strong covalent bonds are also slow.



- **Temperature :** Usually, the higher the temperature, the faster the reaction. The temperature effect is discussed in terms of activation energy. Thermodynamically, a reaction can be exothermic or endothermic as represented below.
- **Concentration effect:** The dependences of reaction rates on concentrations are called rate laws. Rate laws are the expressions of rates in terms of the concentrations of reactants.These rate laws can be in differential forms or integrated forms. They are called differential rate laws and integrated rate laws.
- Rate laws apply to both homogeneous and heterogeneous reactions. In homogeneous reactions, all reactants and products are in one phase (solution), but in heterogeneous reactions, reactants are present in more than one phase. For heterogeneous reactions, the rates are affected by surface areas.
- **Catalysts :** substances used for facilitating reactions. By the nature of the term, catalysts play important roles in chemical reactions.

  Four criteria must be satisfied in order for something to be classified as catalyst.
- Catalysts increase or decrease the rate of reaction affecting activation energy.
- Catalysts are not consumed by the reaction.
- A small quantity of catalyst should be able to affect the rate of reaction for a large amount of reactant.
- Catalysts do not change the equilibrium constant for the reaction. They speed up the rates of the forward and reverse reactions equally, so the equilibrium constant for the reaction remains the same.
- Catalysts increase the rates of reactions by providing a new mechanism that has a smaller activation energy, as shown in the figure below. A larger proportion of the collisions that occur between reactants now has enough energy to overcome the activation energy for the reaction. As a result, the rate of reaction increases.

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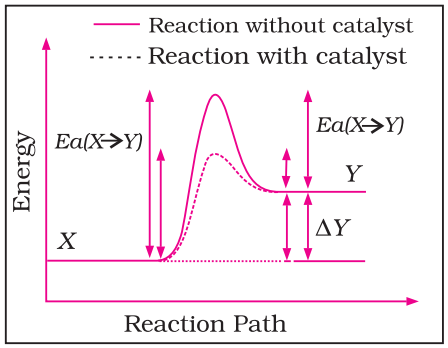

- **Velocity of a reaction :** One cannot determine the velocity of a reaction because a reaction does not proceed at a constant rate. Hence, the velocity of a reaction may be defined as the rate of reaction at a particular given moment, *i.e.* at a specific time.
- If we consider a very small interval of time '*dt*' in which the change in concentration *dx* is taken to be nearly constant then the velocity of reaction is given by :

  Velocity of Fraction $= \frac{dx}{dt}$
- Velocity of reaction is actually the instantaneous rate of reaction.

Rate expression and rate constant: Consider a general reaction

$$\text{Reactants} \rightarrow \text{Products}$$

According to the law of mass action, rate of reaction is directly proportional to active mass, hence, for the above reaction:

$$\text{Rate of reaction} \propto [\text{Reactants}]$$

$$\text{Rate of reaction} = K[\text{Reactants}]$$

- This expression is called rate expression and K is called rate constant (velocity constant).

Characteristics of rate constant :

- It has a fixed value at a particular temperature.
- Value of K varies with temperature.
- Value of K remains unaltered with the change in the concentration of reactants.
- **Order of a reaction :** It is defined as the sum of all the exponents of the reactants involved in the rate equation. However, as all the molecules in reaction do not affect or determine the value of the order of reaction, only those molecules are considered whose concentration undergo a change during the course of reaction. For example,

$$2NO + O_2 \rightarrow 2NO_2$$

$$dx/dt = K[NO]^2 [O_2]$$

The reaction is the 3rd order reaction.

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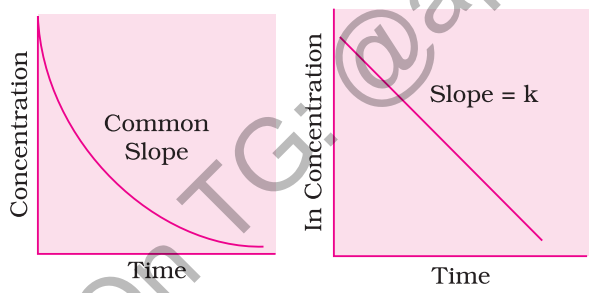
- **First-order reactions :** These are reactions in which only one molecule undergoes a chemical change, *i.e.* first order reaction depends on the concentration of only one reactant. Other reactant can be present, but each will be zero order e.g.

$$N_2O_5 \rightarrow 2NO_2 + \frac{1}{2} O_2$$

- First-order reactions often have the general form [A] products. The differential rate for the first-order reaction is as follows :

$$\text{rate} = -\Delta[A] / \Delta t = k[A]$$

- If the concentration of A is doubled, the reaction rate doubles; if the concentration of A is increased by a factor of 10, the reaction rate increases by a factor of 10, and so forth. Because the units of the reaction rate are always moles per litre per second, the units of the first-order rate constant are reciprocal second (s^{-1}).
- **Graphs of the first-order reaction :** *The expected shapes of the curves for the plots of reactant concentration versus time (light) and the natural logarithm of reactant concentration versus time (right) for the first-order reaction.*



- **Second order reactions :** These are reactions in which two molecules undergo a chemical change, e.g.,

$$2CH_3CHO \rightarrow 2CH_4 + 2\ CO$$

- The differential rate law for the simplest second-order reaction in which 2A → products is as follows:

$$\text{rate} = -\Delta[A] / 2\Delta t = k[A]^2$$

- Consequently, doubling the concentration of A quadruples the reaction rate. For the units of the reaction rate to be moles per litre per second (M/s), the units of the second-order rate constant must be the inverse ($M^{-1} \cdot s^{-1}$).
- In addition to the simple second-order reaction , another very common second-order reaction has the general form A+B →products in which the reaction is the first order in AA and the first order in BB. The differential rate law for this reaction is as follows :

$$\text{rate} = -\Delta[A]/ \Delta t = \Delta[B]/ \Delta t = k[A][B]$$

Because the reaction is first order both in A and in B, it has an overall reaction order of 2.

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- **Third order reactions :** These are reactions in which three molecules undergo a chemical change, e.g.,

$$2NO + O_2 \rightarrow 2NO_2$$

There are several different ways to write a rate law for the third order reaction. One might have cases where Rate = $k[A]^3$,

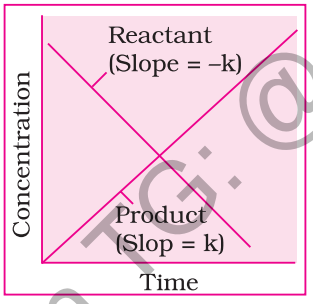
Or Rate = $k[A]^2[B]$,

Or Rate = $k[A][B][C]$.

- **Zeroth-order reaction:** It is one whose rate is independent of concentration, its differential rate law is rate = k. These reactions are considered as zeroth order because one could also write their rate in a form such that the exponent of the reactant in the rate law is 0:

rate = – Δ [A] Δt = k [reactant] 0 = k (1) = k

rate = –Δ [A] Δt = k [reactant] 0 = k (1) = k



Because rate is independent of reactant concentration, a graph of the concentration of any reactant as a function of time is a straight line with a slope of k. The value of k is negative because the concentration of the reactant decreases with time. Conversely, a graph of the concentration of any product as a function of time is a straight line with a slope of k, a positive value.

- **The graph of a zeroth-order reaction:** The change in the concentration of reactant and product with time gives a straight line.
- The decomposition of N_2O on a platinum (Pt) surface to produce N_2 and O_2, which occurs at temperatures ranging from 200°C to 400°C:

$$2N_2O(g) \xrightarrow{pt} 2N_2(g) + O_2(g)$$

- Without a platinum surface, the reaction requires temperatures greater than 700°C, but between 200°C and 400°C, the only factor that determines how rapidly N_2O decomposes is the amount of Pt surface available.

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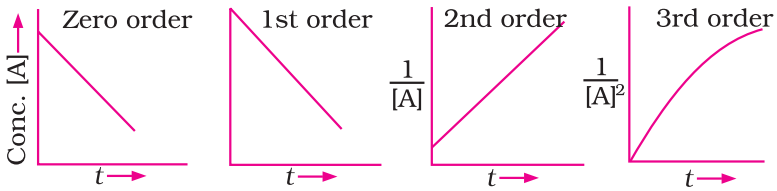
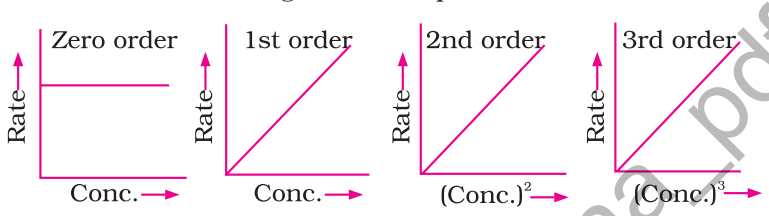


(b) Plots from integrated rate equations:



- **Half-Life of the First and Second Order Reactions**; The half-life (*hl*) of a reaction is the time period required to reduce the reactant to half of its original value. The half-life of the first order reaction is a constant, independent of the initial concentration. The rate constant and half-life has the relationship:

$$hl = ln(2) \ / \ k$$

- For the second order reaction, the half-life depends on the initial concentration, $[A]_o$, and the rate constant *k*:

$$hl = 1 \ / \ (k\,[A]_o)$$

$$hl \ x \ k\,[A]_o = 1$$

- Since the concentration is reduced to half of its original value at the end of its first half-life, the second half-life is twice as long as the first half-life. Thus, a plot of [A] vs. *t* easily reveals the order of the reaction by tracking its half life.
- A summary of the relationships for the first and second order reactions is given below :

	Differential rate law	**Integrated rate law**	**Linear plot**	**Half life**
First order	- d[A]/dt	$[A] = [A]_o \exp$	ln [A] vs *t*	*hl*=ln(2)/*k*
	= *k* [A]	(-*k t*)	slope = - *k*	
Second order	- d[A]/dt = *k* [A]²	$\frac{1}{[A]} - \frac{1}{[A]_o} = kt$	$\frac{1}{[A]}$ slope k	slope = *k*

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Chapter 21

QUALITATIVE ANALYSIS

Qualitative analysis, physical appearance of salts, colour of ions in aqueous solution, colour of different salts, flame test, colour of different gases, Bead test, tests for anions with confirmatory tests for chloride, bromide, iodide, carbonate, sulphate, nitrate, phosphate, acetate and oxalate ions.

- **Qualitative chemical analysis :** It's a branch of chemistry that deals with the identification of elements or grouping of elements present in a sample. The techniques employed in qualitative analysis vary in complexity, depending on the nature of the sample:

Physical appearance of inorganic salts	
Salt	**Colour**
MnO, MnO_2, FeO, CuO, Co_3O_4, Ni_2O_3; sulphides of	Black
Ag^+, Cu^+, Cu^{2+}, Ni^{2+}, Fe^{2+}, Co^{2+}, Pb^{2+}, Hg^{2+}, Bi^{3+} Hydrated Cu^{2+} salts	Blue
HgO, HgI_2, Pb_3O_4	Red
Cr^{3+}, Cr^{6+}, Ni^{2+}, hydrated Fe^{2+} salts	green
Hydrated Mn^{2+} salts	Light pink
KO_2, $K_2Cr_2O_7$, Sb_2S_3, Ferrocyanide	Orange
Hydrated Co^{2+} salts	Reddish-pink
Chromates, AgBr, As_2S_3, AgI, PbI_2, CdS	Yellow
CdO, Fe_2O_3, PbO_2, $CuCrO_4$	Dark brown

Colour of ions in aqueous solution		
Name	**Formula**	**Colour**
Alkali metals	M^+	Colourless
Alkaline earth metals	M^{2+}	Colourless
Scandium (III)	Sc^{3+}	Colourless
Titanium(III)	Ti^{3+}	Violet
Titanium(IV)	Ti^{4+}	Colourless
Vanadium (II)	V^{2+}	Lavender
Vanadium(III)	V^{3+}	Dark grey-green
Chromium(III)	Cr^{3+}	Blue green-grey
Chromate	$Cr_2O_4^-$	Yellow
Dichromate	$Cr_2O_7^{2-}$	Orange
Manganese(II)	Mn^{2+}	Pale pink
Manganate(V)	MnO_4^{3-}	Deep blue

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Name	Formula	Colour
Permanganate	MnO_4^{1-}	Deep purple
Iron(II)	Fe^{2+}	Very pale green
Iron(III)	Fe^{3+}	Pale violet brown
Iron(III) tetrachlorocomplex	$FeCl_4^-$	Yellow-brown
Nickel(II)	Ni^{2+}	Light green
Cobalt(II)	Co^{2+}	Pink
Copper(II)	Cu^{2+}	Blue
Zinc(II)	Zn^{2+}	Colourless
Silver(I)	Ag^{1+}	Colourless

Colour of different salts

Name	Formula	Colour
Copper(II) sulphate (anhydrous)	$CuSO_4$	White
Copper(II) sulphate pentahydrate	$CuSO_4 \cdot 5H_2O$	Blue
Copper(II) benzoate	$Cu(C_7H_5O_2)_2$	Blue
Cobalt(II) chloride	$CoCl_2$	Deep blue
Cobalt(II) chloride hexahydrate	$CoCl_2 \cdot 6H_2O$	Deep magenta
Manganese(II) chloride tetrahydrate	$MnCl_2 \cdot 4H_2O$	Pink
Copper(II) chloride dihydrate	$CuCl_2 \cdot 2H_2O$	Blue-green
Nickel(II) chloride hexahydrate	$NiCl_2 \cdot 6H_2O$	Green
Lead(II) iodide	PbI_2	Yellow

Flame test : Flame colour of alkali and alkaline earth metals flame.

Name	Formula	Colour
Lithium	Li	Red
Sodium	Na	Yellow/Orange
Magnesium	Mg	Brilliant white
Potassium	K	Lilac/Violet
Calcium	Ca	Brick Red
Rubidium	Rb	Pink/Red
Strontium	Sr	Red
Caesium	Cs	Light blue
Barium	Ba	Green/Yellow

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Colour of different gases :

Name	Formula	Colour
Hydrogen	H_2	Colourless
Oxygen	O_2	Colourless
Fluorine	F_2	Pale yellow/Brown
Chlorine	Cl_2	Greenish-yellow
Bromine	Br_2	Reddish-brown
Iodine	I_2	Dark purple
Chlorine dioxide	ClO_2	Dark yellow
Dichlorine monoxide	Cl_2O	Brown/yellow
Nitrogen dioxide	NO_2	Dark brown
Dinitrogen tetroxide	N_2O_4	Colourless

- **Bead test :** A variety of colours, often similar to the colours found in a flame test, are produced in a bead test, which is a qualitative test for determining metals. A platinum loop is moistened and dipped in a fine powder of the substance in question and Borax. The loop with the adhered powder is then heated in a flame until it fuses and the colour of the resulting bead observed.

Colours exhibited by metals in the bead test		
Metal	**Oxidizing flame**	**Reducing flame**
Aluminium	colourless (hot and cold), opaque	colourless, opaque
Antimony	colourless, yellow or brown (hot)	grey and opaque
Barium	colourless	
Bismuth	colourless, yellow or brownish (hot)	grey and opaque
Cadmium	colourless	grey and opaque
Calcium	colourless	colourless
Cerium	Red (hot)	colourless (hot and cold)
Chromium	Dark yellow (hot), green (cold)	green (hot and cold)
Cobalt	Blue (hot and cold)	blue (hot and cold)
Copper	Green (hot), blue (cold)	red, opaque (cold), colourless (hot)
Gold	Golden (hot), silver (cold)	red (hot and cold)
Iron	yellow or brownish red (hot and cold)	green (hot and cold)
Lead	colourless, yellow or brownish (hot)	grey and opaque

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Magnesium	colourless	Colourless
Manganese	violet (hot and cold)	colourless (hot and cold)
Molybdenum	colourless	yellow or brown (hot)
Nickel	brown, red (cold)	grey and opaque (cold)
Silicon	colourless (hot and cold), opaque	colourless, opaque
Silver	colourless	grey and opaque
Strontium	colourless	Colourless
Tin	colourless (hot and cold), opaque	colourless, opaque
Titanium	colourless	yellow (hot), violet (cold)
Tungsten	colourless	Brown
Uranium	Yellow or brownish (hot)	Green
Vanadium	colourless	Green

- **Test for anions :** Anions are identified by performing the following tests below:
- **Diluted H_2SO_4 Test :** When a pinch of the salt is treated with dil. H_2SO_4, a gas is evolved. The identification of gas helps identify the anion.

Carbonate : On treating the solid carbonate, CO_2 is given off in the cold with brisk effervescence.

$$CaCO_3 + CaSO_4 \rightarrow CaSO_4 + H_2O + CO_2 \uparrow$$

Sulphide : Sulphides when treated with dil. H_2SO_4 give H_2S gas.

$$ZnS + H_2SO_4 \rightarrow ZnSO_4 + H_2S \uparrow$$

H_2S is characterized by its offensive smell like that from rotten eggs.

Sulphite : On heating solid sulphite with dil.H_2SO_4, SO_2 gas is evolved.

$$Na_2SO_4 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + SO_2\uparrow$$

Nitrite : On treating solid nitrite with dil. H_2SO_4, nitric oxide (NO) gas is evolved which readly gives brown fumes of NO_2 with the oxygen of the air.

$$3KNO_2 + 3H_2SO_4 \rightarrow 3KHSO_4 + 3HNO_2$$
$$3HNO_2 \rightarrow HNO_3 + H_2O + 2NO$$
$$3KNO_3 + 3H_2SO_4 \rightarrow 3KHSO_4$$

- **Conc. H_2SO_4 Test :** If no action takes place with dil. H_2SO_4, warm a pinch of the salt with conc. H_2SO_4 and identify the gas evolved.

Chemical Reactions Involved in Conc. H_2SO_4 Test

- **Chlorides:** Chloride salts react with conc. H_2SO_4 to evolve hydrogen chloride (HCl) gas.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl\uparrow$$
(Sodium bisulphate)

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- **Bromides :** Bromide salts react with conc. H_2SO_4 to evolve bromine gas.

  $NaBr + H_2SO_4 \rightarrow NaHSO_4 + HBr$

  $H_2SO_4 + 2HBr \rightarrow 2H_2O + SO_2 + Br_2\uparrow$
- **Iodides :** Iodide salts react with conc. H_2SO_4 to evolve the vapour of iodine.

  $KI + H_2SO_4 \rightarrow KHSO_4 + HI$

  $H_2SO_4 + 2HI \rightarrow 2H_2O + SO_2 + I_2\uparrow$
- **Nitrates :** Upon reaction with conc.H_2SO_4, nitrates evolve NO_2 gas.

  $KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$

  $HNO_3 + C_{(Paper\ pellet)} \rightarrow 2H_2O + CO_2 + 4NO_2\uparrow$
- **Acetates :** Acetates react with conc. H_2SO_4 to produce the vapour of acetic acid.

  $CH_3COONa + H_2SO_4 \rightarrow NaHSO_4 + CH_3COOH\uparrow$ Acetic Acid
- **Oxalates :** Oxalate salts react with conc. H_2SO_4 to evolve a mixture of carbon dioxide and carbon monoxide.

  $$\begin{matrix} COONa \\ | \\ COONa \end{matrix} + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + CO_2 + CO + H_2O$$

Independent Group (SO_4^{2-} and PO_4^{3-}) Test

- If the salt does not react with dil H_2SO_4 as well as with conc. H_2SO_4 test for $SO_4^{2-}$and PO_4^{3-} by performing their individual tests.
- **Potassium permanganate Test**: The test is performed by using dilute sulphuric acid and potassium permanganate as reagents. This test helps in the detection of Cl^-, Br^-, I^- and $C_2O_4^{2-}$.

Chemical reactions involved in potassium permanganate test include:

$$2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$$

Chlorides : $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

$2HCl + [O] \rightarrow H_2O + Cl_2$

Bromides : $NaBr + H_2SO_4 \rightarrow NaHSO_4 + HBr$

$2HBr + [O] \rightarrow H_2O + Br_2$

Iodides : $NaI + H_2SO_4 \rightarrow NaHSO_4 + HI$

$2HI + [O] \rightarrow H_2O + I_2$

Oxalate ions:

$$\begin{matrix} COONa \\ | \\ COONa \end{matrix} + H_2SO_4 \rightarrow \begin{matrix} COOH \\ | \\ COOH \end{matrix} + Na_2SO_4$$

$$\begin{matrix} COOH \\ | \\ COOH \end{matrix} + [O] \rightarrow H_2O + CO_2$$

Wet Tests for Acid Radicals (Anions) :

Confirmation of Carbonate (CO_3^{2-})

- **Reaction with dil HCl :** Carbonate on reaction with dil. HCl gives CO_2 gas that reacts with lime water to produce a white precipitate of calcium carbonate that turns lime water milky. In case of soluble

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gets carbonate, this test is performed with water extract and in case of insoluble carbonates, this test is performed with the solid salt.

$CaCO_3 + 2HCl \rightarrow CaCL_2 + CO_2 + H_2O$

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3\ H_2O$

- **Magnesium sulphate test :** The test is performed in the case of soluble carbonates only. Soluble carbonates react with the magnesium sulphate solution to form a white precipitate of magnesium carbonate.

$Na_2CO_3 + MgSO_4 \rightarrow MgCO_3 \downarrow + Na_2SO_4$

Sodium carbonate White precipitate

Confirmation of Sulphite (SO_3^{2-})

- **Barium chloride test :** Sulphites on reaction with barium chloride to form a white precipitate of barium sulphite. Barium sulphite gets dissolved in dil. HCl with the evolution of sulphur dioxide gas.

$Na_2SO_4 + BaCl_2 \rightarrow 2NaCl + BaSO_4$

- **Potassium permanganate test** : The colour of potassium permanganate is discharged when it reacts with sulphite.

$2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$

- **Potassium dichromate test :** A green colour is obtained when sulphites react with potassium dichromate solution.

$K_2Cr_2SO_3 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3[O]$

$Na_2SO_3 + [O]\ Na_2SO_4$

Confirmation of Sulphide (S_2^-)

- **Sodium nitroprusside test :** Sulphides give a violet or purple colouration with the sodium nitroprusside solution due to the formation of $Na_4[Fe(CN)_5NOS]$.

$Na_2S + Na_2\ [Fe(CN)_5\ NO] \rightarrow Na_4\ [Fe\ (CN)_5\ NOS]$

Sodium nitroprusside (Violet or Purple Colouration)

- **Lead acetate test :** Sulphides react with lead acetate to form a black precipitate of lead sulphide.

$Na_2S + (CH_3COO)_2\ Pb \rightarrow PbS\downarrow + 2CH_3COONa$

Black precipitate

- **Cadmium carbonate test :** Sulphides react with a suspension of cadmium carbonate to form a yellow precipitate of cadmium sulphide.

$Na_2S + CdCO_3 \rightarrow CdS\uparrow + Na_3CO_3$

(Yellow precipitate)

Confirmation of Nitrite (NO_2^-)

- **Ferrous sulphate test :** Nitrites give a dark brown or black colouration in ferrous sulphate test due to the formation of $FeSO_4$. NO, dark brown or black colour is observed.

$KNO_2 + CH_3COOH \rightarrow CH_3COOK + HNO_2$

$3HNO_2 \rightarrow HNO_3 + 2NO + H_2O$

$FeSO_4 + NO \rightarrow FeSO_4.NO$

- **Starch - Iodide test :** Nitrites react with potassium iodide in the presence of dilute sulphuric acid to liberate iodine. Iodine forms a blue-black complex with starch.

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$2KI + 2H_2SO_4 + 2HNO_2 \rightarrow 2KHSO_4 + I_2 + 2NO + 2H_2O$

I_2 + Starch $\rightarrow$ Blue-black complex

- **Diphenylamine test :** In the presence of nitrites, diphenylamine is oxidised, giving a blue colouration.

Confirmation of Nitrate (NO_3^-)

- **Copper chips test :** In this reaction, copper chips reduce nitrates to reddish-brown NO_2 gas.
- **Brown-ring test :** This test is performed by adding a solution of iron (II) sulphate to a solution of nitrate, followed by the slow addition of concentrated sulphuric acid, so that the sulphuric acid may form a layer below the aqueous solution. The formation of a brown ring at the junction of two layers indicates the presence of nitrate.
- The overall reaction is the reduction of nitrate ion by iron (II) which is reduced to iron (I) and there is formation of a nitrosonium complex where nitric oxide is oxidised to NO^+.

$KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$

$6FeSO_4 + 3H_2SO_4 + 2HNO_3 \rightarrow 3Fe_2(SO_4)_3 + 4H_2O + 2NO$

$FeSO_4 + NO + 5H_2O \rightarrow [Fe(NO)(H_2O)_5]SO_4$

(Brown ring)

Confirmation of Chloride (Cl^-)

Silver nitrate test : Chlorides on reaction with silver nitrate solution to form a white precipitate of silver chloride which is soluble in ammonium hydroxide.

$NaCl + AgNO_3 \rightarrow AgCl\downarrow + NaNO3$

White Precipitate

$NgCl + 2NH_4OH \rightarrow [Ag\ (NH_3]_2]\ Cl + 2H_2O$

Soluble Complex

- **Chromyl chloride test :** When chloride salts react with potassium dichromate and conc. sulphuric acid red fumes of chromyl chloride are formed which react with sodium hydroxide to form yellow solution of sodium chromate. Sodium chromate reacts with lead acetate in the presence of dil. acetic acid to form the yellow precipitate of lead chromate.

$4NaCl + K_2Cr_2O_7 + 3H_2SO_4 \rightarrow 2Na_2SO_4 + K_2SO_4 + 2CrO_2Cl_2\uparrow + 3H_2O$

Chromyl Chloride

: (Red Fumes)

$CrO_2Cl_2 + 4NaOH \rightarrow Na_2CrO_4 + 2H_2O + 2NaCl$

Sodium Chromate

$Na_2CrO_4 + (CH_3COO)_2Pb \rightarrow PbCrO_2 + 2CH_3COONa$

Lead Chromate

(Yellow precipitate)

Confirmation of Bromide (Br^-) :

Silver nitrate test : Bromides on reaction with silver nitrate solution form a pale yellow precipitate of silver bromide which is sparingly soluble in ammonium hydroxide.

$KBr + AgNO_3 \rightarrow KNO_3 + AgBr$

- **Manganese dioxide test :** When bromide salts react with

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manganese dioxide and concentrated sulphuric acid, bromine gas is liberated.

$$2KBr + MnO_2 + 3H_2SO_4 \rightarrow 2KHSO_4\ 2H_2O + MnSO_4 + Br_2\uparrow$$

- **Chlorine water test :** Bromine liberated in this test being soluble in carbon disulphide imparts an orange colour to the carbon disulphide layer.

$$2KBr + Cl_2 \rightarrow 2KCl + Br_2$$

- Similarly, silver mirror test, manganese dioxide test and chlorine water tests can be adopted to confirm the presence of iodide ions

$$KI + AgNO_3 \rightarrow KNO_3 + AgI$$

$$2KI + MnO_2 + 3H_2SO_4 \rightarrow 2KHSO_4 + MnSO_4 + 2H_2O + I_2$$

$$2KI + Cl_2 \rightarrow 2KCl + I_2$$

- **Oxalic acid test :** Oxalic acid reacts with acetate salt to form acetic acid which has a characteristic vinegar-like smell.

$$\begin{matrix} COOH \\ | \\ COOH \end{matrix} + 2CH_3COONa \rightarrow \begin{matrix} COONa \\ | \\ COONa \end{matrix} + 2CH_3COOH$$

- **Ester test :** Acetate salts react with conc. sulphuric acid and ethyl alcohol to form the ester, ethyl acetate which has a fruity smell.

$$2CH_3COONa + H_2SO_4 \rightarrow Na_2SO_4 + 2CH_3COOH$$

$$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$$

Ethyl acetate
Fruity smell)

Confirmation of Oxalate ($C_2O_4^{2-}$)

- **Calcium chloride test :** Oxalate salts react with calcium chloride to form the white precipitate of calcium oxalate.

$$(NH_4)_2C_2O_4 + CaCl_2 \rightarrow CaC_2O_4\downarrow + 2NH_4Cl$$

White precipitate

- **Potassium permanganate test :** The pink colour of potassium permanganate is decolourised with the evolution of carbon dioxide gas.

$$2KMnO_4 + 3H_2SO_4 + 5H_2C_2O_4 \rightarrow K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O$$

Oxalic acid

Confirmation of Sulphate (SO_4^{2-})

- Barium chloride test: Sulphates react with barium chloride to form the white precipitate of barium sulphate.

$$Na_2SP_4 + BaCl_2 \rightarrow BaSO_4\downarrow + 2NaCl$$

White precipitate

- Lead acetate test: Sulphates react with lead acetate to form the white precipitate of lead sulphate.

$$Na_2SO_4 + (CH_3COO)_2Pb \rightarrow PbSO_4\downarrow + 2CH_3COONa$$

White ppt.

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Confirmation of Phosphate (PO_4^{3-}) :

- **Ammonium molybedate test :** Phosphate salts react with ammonium molybdate solution to form a deep yellow precipitate of ammonium phosphate molybedate. The chemical reaction is as follows :

$$K_3PO_4 + 3(NH_4)_2MoO_4 \rightarrow 2(NH_4)_3PO_4 + 3K_2MoO_4$$

Ammonium molybedate — Potassium molybedate

$$K_2MoO_4 + 2HNO_3 \rightarrow H_2MoO_4 + 2KNO_3$$

Molybdic acid

$$H_2MoO_4 \rightarrow MoO_3 + H_2O$$

$$(NH_4)_3PO_4 + 12MoO_3 + 6H_2O \rightarrow (NH_4)_3PO_4.12MoO_3.6H_2O$$

Ammonium phosphate molybdic (Yellow precipitate)

- **Magnesia mixture test :** Phosphate salts react with magnesia mixture to form the white precipitate of magnesium ammonium phosphate.

$$Na_2HPO_4 + MgCl_2 + NH_4OH \rightarrow Mg(NH_4)PO_4\downarrow + 2NaCl + H2O$$

Disodium hydrogen Phosphate — Magnesium ammonium phosphate (white precipitate)

- Magnesia mixture is produced by adding solid NH_4Cl to magnesium chloride solution followed by boiling, cooling and adding NH_4OH till a strong smell of ammonia is obtained.

Miscellaneous

(i) Important discoveries of chemistry

Discovery	Discoverer	Discovery	Discoverer
Nitrogen	Rutherford	Uncertainty	Heisenberg
pH scale	Lowarance	Radioactivity	H. Bacqueral
Heavy water	Ure	Group displacement	Soddy & Fajan
Calcium	Devi	Law of Partial pressure	Dalton
Sodium	Devi	Law of inverse ratio	Rietcher
Potassium	Devi	Photo electric effect	Einstein
Isotope	Soddy	Electro valency	Kossel
Dilution law	Ostwald	Artifical radio activity	Juiot/Juliate
Catalyst	Berzealius	Theory of wave machanics	De Brogeli
Hydrogen	Cavendish	Theory of relativity	Einstein
Covalencey	Lewis	Law of mass action	Lavoisier
Helium	Locare	Polenium	Madame Curie
Nucleus	Rutherford	Exclusion principle	Pauli

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Discovery	Discoverer	Discovery	Discoverer
Thorium	Berzealius	Atomic Number	Moseley
Uranium	Cloproth	Radium	Mad. Curie
Proton	Goldstein	Modern periodic table	Moseley
Electron	J.J. Thomson	Old periodic table	Mendleeve
Neutron	J. Chadwick	Law of gaseous diffusion	Grahm
Octate rule	Nelands	Maximum Multiplicity rule	Hund
Magnesium	Devi	Treble law	Dobrineor
Messon	Yukawa	Quantum theory	Max. Planck
Positron	Anderson	Atomic theory	J. Dalton
Oxygen	Shielley & Pristley	Law of electrolytic decomposition	Faraday
Argon	Ramssa & Raleigh	Law of constant proportion	Prout

(ii) Chemical formulae, commercial names of chemical compounds

Commercial Name	Chemical Compound	Chemical formula
Common salt	Sodium chloride	$NaCl$
Baking soda	Sodium bicarbonate	$NaHCO_3$
Washing soda	Sodium carbonate	$Na_2CO_3.10H_2O$
Caustic Soda	Sodium hydroxide	$NaOH$
Chilli salt peter	Sodium nitrate	$NaNO_3$
Borax	Sodium borate	$Na_2B_4O_7.\ 10H_2O$
Soda ash	Sodium carbonate	Na_2CO_3
Globour salt	Sodium sulphate	$Na_2SO_4.10H_2O$
Hyposulphate	Sodium thiosulphate	$Na_2S_2O_3.5H_2O$
Microcosmic salt	Sodium ammonium hydrogen phosphate	$NaNH_4.HPO_4$
Potash alum	Potassium aluminium sulphate	$K_2SO_4Al_2(SO)_3.\ 24H_2O$
Chinese white	Zinc oxide	ZnO
Quick silver	Mercury	Hg
Calomel	Mercuric chloride	Hg_2Cl_2
Vermillion	Mercuric sulphide	HgS
Corrosive sublimate	Mercurous chloride	$HgCl_2$
Heavy hydrogen	Deuterium	D_2O
Silica	Silicon dioxide	SiO_2

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Commercial Name	Chemical Compound	Chemical formula
Arsin	Arenic hydride	AsH_3
Blue vitriol	Copper sulphate	$CuSO_4.5H_2O$
Lithopone	Mixture of zinc sulphide and barium sulphate	$ZnS + BaSO_4$
Producer gas	Mixture of carbon mon-oxide and nitrogen gas	$CO + N_2$
Marsh gas	Methane	CH_4
Gammaxine	Benzene hexachloride (BHC)	$C_6H_6Cl_6$
Phosgene	Carbonyl chloride	$COCl_2$
Vinegar	Dilute solution of acetic acid	CH_3COOH
Alcohol	Ethyl alcohol	C_2H_5OH
Wood spirit	Methyl alcohol	CH_3OH
Starch	—	$n(C_6H_{10}O_5)$
TNT	Trinitro toluene	$C_6H_2CH_3 (NO_2)_3$
Juice of grapes	Glucose	$C_6H_{12}O_6$
Formalin	10% solution of formaldehyde	dil.HCHO
Freon	Dichloro difluoro carbon	CF_2Cl_2
Urea	Carbamyde	NH_2CONH_2
Chloroform	Tri chloro methane	$CHCl_3$
Iodoform	Tri iodo methane	CHI_3
Pyrine	Carbon tetra chloride	CCl_4
Phenol	Hydroxy benzene or carbodic acid	C_6H_5OH
MIC	Methyl isocynate	CH_3NC
Red medicine	Potassium permanganate	$KMnO_4$
Niter	Potassium nitrate	KNO_3
Chrome alum	Potassium chromium sulphate	$K_2SO_4.Cr(SO_4).24H_2O$
Bleaching powder	Calcium oxy dichloride	$Ca(OCl)CI$ or $CaOCl_2$
Lime water	Calcium hydroxide	$Ca(OH)_2$
Gypsum	Calcium sulphate	$CaSO_4.2H_2O$

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Commercial Name	Chemical Compound	Chemical formula
Plaster of Paris	Calcium sulphate hemihydrate	$CaSO_4.1/2H_2O$
Chalk or Marble	Calcium carbonate	$CaCO_3$
Slaked lime	Calcium oxide	CaO
Limestone	Calcium carbonate	$CaCO_3$
Hydrolith	Calcium hydride	CaH_2
Sal-ammoniac	Ammonium chloride	NH_4Cl
Laughing gas	Nitrous Oxide	N_2O
Letharge	Lead Oxide	PbO
Galena	Lead sulphide	PbS
Red vermillion	Lead peroxide	Pb_3O_4
White lead	Basic lead carbonate	$2PbCO_3$. Pb $(OH)_2$
Acid of salt	Hydrogen chloride	HCl
—	Nitric acid	HNO_3
Meuretic acid	Hydrochloric acid	HCl
Oil of vitriol	Conc.sulphuric acid	Conc.H_2SO_4
Aquaregia	Mixture of conc. nitric acid and conc. hydro-chloric acid (1: 3)	HNO_3 + 3HCl
Water gas	Mixture of carbon monoxide and hydrogen	CO + H_2
Oleum	Fuming sulphuric acid	$H_2S_2O_7$
Bauxite	Hydrated alumina	Al_2O_3. $2H_2O$
Solid ice	Solid carbon dioxide	CO_2(s)
Green vitriol	Ferrous sulphate	$FeSO_4$. $7H_2O$
Magnesia	Magnesium oxide	MgO
Horn silver	Silver chloride	AgCl
Lunar caustic	Silver nitrate	$AgNO_3$
Black Zinc	Zinc sulphide	ZnS
White vitriol	Zinc sulphate	$ZnSO_4$.$7H_2O$

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Chapter 22

ORGANIC CHEMISTRY

Hydrocarbons, aliphatic and aromatic hydrocarbons, homologous series, isomerism, functional groups, stereiomerism, geometrical isomerism, cis-trans isomers, preparation and properties of alkanes, alkenes and alkynes.

- **Hydrocarbons :** These are chemical compounds composed only of the elements, carbon (C) and hydrogen (H) or their derivatives. The carbon atoms join together to form the framework of the compound, the hydrogen atoms attach to them in many different configurations. These are found naturally or are synthesized artificially with urea being the first organic compound to be synthesized in a laboratory. Initially, they were considered to be the compounds of biological origin. Presently, they are found to be the principal constituents of petroleum and natural gas. They serve as fuels and lubricants as well as raw materials for the production of plastics, fibres, rubbers, solvents, explosives, etc.
- **Origin of terms : Aliphatic and Aromatic compounds :** From the 19th century onwards, chemists classified hydrocarbons as either aliphatic or aromatic on the basis of their sources and properties. Aliphatic described hydrocarbons derived by the chemical degradation of fats or oils. Aromatic hydrocarbons constituted a group of related substances obtained by the chemical degradation of certain pleasant-smelling plant extracts. The terms *aliphatic* and *aromatic* are retained in modern terminology, but the compounds they describe are distinguished on the basis of structure rather than origin.
- **Aliphatic compounds v/s aromatic compounds :** Aliphatic hydrocarbons have long straight, branched or ring chain structures. They have further been divided into three main groups according to the types of bonds they contain: alkanes, alkenes and alkynes.

Aliphatic Hydrocarbons

- Acyclic aliphatic (Open-Chain hydrocarbons)
  - Saturated acyclic (Only single bonds)
    - 'Alkanes' E.g., C_2H_6 Ethane → $H_3C–CH_3$
  - Unsaturated acyclic (Al least one multiple bond)
    - Alkenes (Double bond) E.g., C_2H_4 Ethene → $H_2C=CH_2$
    - Alkynes (Triple bond) E.g., C_2H_2 Ethyne → $HC = CH$
- Cyclic aliphatic (or) cycloalkanes (or) Alicyclic compounds (Closed chain aliphatic hydrocarbons) E.g., C_6H_{10} Cyclohexane

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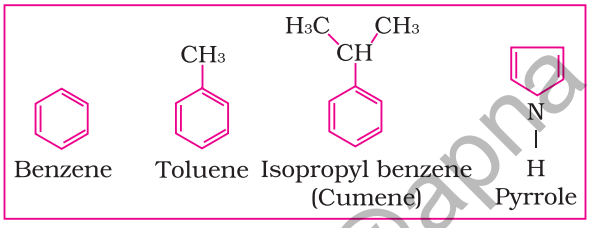
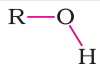
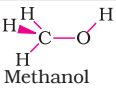
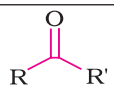
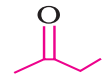
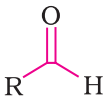
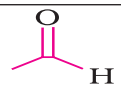
- Alkanes also called paraffins have only single bonds with structural formula C_nH_{2n+2}, n being the number of carbon atoms. Alkenes have a single or more carbon-carbon double bond with structural formula, C_nH_{2n}.
- Alkynes have a carbon-carbon triple bond with structural formula, $C_n H_{2n-2}$.
- Aromatic hydrocarbons are significantly more stable than their Lewis structures, *i.e.* they possess "special stability". They are classified as either arenes, which contain a benzene ring as a structural unit, or non-benzenoid aromatic hydrocarbons, which lack a benzene ring as a structural unit.



Homologous series : It is a series of compounds with the same general formula, usually varying by a single parameter. It is a series of compounds in which

- each succeeding hydrocarbon differs by '$-CH_2$' group, *i.e.* by 14amu in molecular mass.
- all members have the same functional group so that they may show the same chemical properties.
- all members differ from one another in their physical properties such as melting point, boiling point, density, etc.
- **Functional groups :** Compounds that contain C-O bonds possess differing reactivity based upon the location and hybridization of the C-O bond, owing to the electron withdrawing effect of sp-hybridized oxygen (carbonyl groups) and the donating effects of sp^2-hybridized oxygen (alcohol groups).

Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
Alcohol	Hydroxyl	ROH		hydroxy-	-ol	 Methanol
Ketone	Carbonyl	RCOR'		(-COR') or oxo- (=O)	-one	 Butanone
Aldehyde	Aldehyde	RCHO		formyl- (-COH) or oxo- (=O)	-al	 *(Ethanal)*

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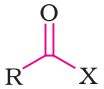
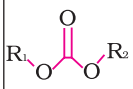
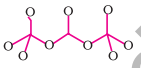
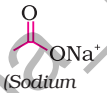
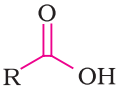
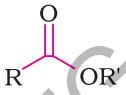
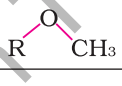
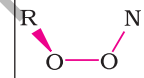
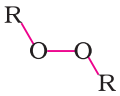
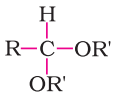
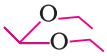
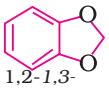
Chemical class	Group	Formula	Structural Formula	Prefix	Suffix	Example
Acyl halide	Haloformyl	RCOX		carbonofluoridoyl-carbonochloridoyl-carbonobromidoyl-	-oyl halide	Acetyl chloride *(Ethanoyl chloride)*
Carbonate	Carbonate ester	ROCOOR		(alkoxycarbonyl)oxy-	alkyl carbonate	 Triphosgene *carbonate)*
Carboxylate	Carboxylate	$RCOO^-$		carboxy-	-oate	 *(Sodium ethanoate)*
Carboxylic acid	Carboxyl	RCOOH		carboxy-	-oic acid	*(Ethanoic acid)*
Ester	Ester	RCOOR'		alkanoyloxy- or alkoxycarbonyl	alkyl alkanoate	*(Ethyl butanoate)*
Methoxy	Methoxy	$ROCH_3$		methoxy-		
Hydroperoxide	Hydroperoxy	ROOH		hydroperoxy-	alkylhydroperoxide	*tert-* Butyl hydroperoxide
Peroxide	Peroxy	ROOR		peroxy-	alkyl peroxide	Di-tert-butyl peroxide
Ether	Ether	ROR'		alkoxy-	alkyl ether	Diethyl ether *(Ethoxyethane)*
Acetal	Acetal	RCH(OR')(OR")		dialkoxy-	-al dialkyl acetal	
Heterocycle	Methylenedioxy	PhOCOPh		methylenedioxy	dioxole	 1,2-*1,3-Benzodioxole*

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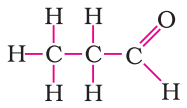
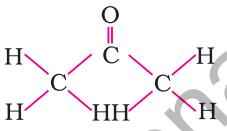
- **Hydrocarbons and isomerism :** Isomerism is the phenomenon in which an organic molecule having the same molecular formula exists in the form of different molecular structures, each having different chemical and physical properties such as ethanol (CH_3CH_2OH) and dimethyl ether (CH_3OCH_3). These molecules are known as isomers.
- Isomerism can be broadly classified as structural isomerism and stereoisomerism which can be further classified in various categories.
- **Structural Isomerism :** It involves the type of isomerism in which isomers have different molecular structures because of different arrangements of atoms. Structural isomers show different orders of connectivity between atoms. Therefore, they show different branching and functional groups.

Propanal and propanone :



Propanal
(Propionaldehyde)



Propanone
(Acetone or
dimethyl ketone)

- **This isomerism has further been classified into six sub-groups.**
- **Chain isomerism :** This type of isomerism shows different skeletons of carbon atoms due to branching while keeping the same molecular formula. Because of branching, the linkage of carbon atoms in the parent chain is different which results in different molecules. Such type of isomerism is also known as nuclear isomerism. Generally, chain isomerism is exhibited by hydrocarbon alkanes like butane, pentane, and so on.

(i) $CH_3 - CH_2 - CH_2 - CH_3$ and $CH_3 - CH(CH_3) - CH_3$

Butane 2, methyl -propane

(ii)

$CH_3-CH_2-CH_2-CH_2-CH_3$ Pentane

$CH_3-CH_2CH(CH_3)-CH_3$ 2, methyl-butane

$CH_3-C(CH_3)_2-CH_3$ 2,2-dimethyl-propane

- **Positional isomerism :** This type of isomerism involves isomers which have the same functional groups or multiples of them at different positions, e.g.,

$CH_2 = CH - CH_2-CH_2-CH_3$ (pent-1-ene) and $CH_3 - CH = CH - CH_2 - CH_3$ (pent-2-ene)

have different positions of the double bond in molecules but show the same molecular formula. Similarly propan-1-ol and propan-2-ol differ in the position of the hydroxyl group at C-1 and C-2 respectively, hence, they show position isomerism.

$CH_3 - CH_2 - CH_2 - OH$ Propan-1-ol and $CH_3 - CH(OH) - CH_3$ Propan-2-ol

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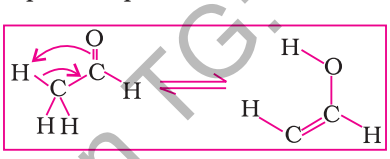
Functional isomerism : This type of isomerism involves isomers which has different functional groups, and therefore belongs to different families. For example: alcohols and ethers are the functional isomers of each other. Some other pairs of functional isomers are:

- Diens, and alkynes
- Nitroalkane and alkyl nitrile
- Primary, secondary and tertiary amines
- Cyanide and isocyanides
- Aromatic alcohols, phenols and ether
- **Metamerism** : This type of isomerism involves isomers which differ in structure because of differences in the distribution of carbon atoms about the functional group. Ether and secondary amines are the best examples of metamerism. For example: ethoxypropane and 1-ethoxypropane are the metamers of each other.

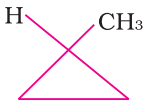
  $CH_3CH_2CH_2\text{-}O\text{-}CH_2CH_3$ and $CH_3\text{-}CH_2\text{-}O\text{-}CH_2\text{-}CH_2\text{-}CH_3$

  Ethoxypropane 1-Ethoxypropane

- **Tautomerism :** It is also called as keto-enol isomers as in this type of isomerism, isomers are in dynamic equilibrium and converts in keto and enol form due to1,3-migration of hydrogen atom. For example : vinyl alcohol and acetaldehyde are the tautomers of each other. Vinyl alcohol shows enol form while acetaldehyde consists of carbonyl group and represents keto form.



- **Ring-chain isomerism:** In this type of isomerism, one isomer possesses an open-chain structure while the other has a cyclic structure. For example: propane and cyclo propane are ring-chain isomers of each other. Other examples of ring-chain isomerism are propyne and cyclopropene, But-1-ene, cyclobutane and methylcyclopropane.

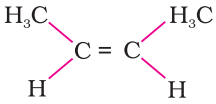


$H_2 - CH_2 - CH = CH_2$

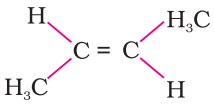
But-1-ene Cyclobutane Methyl cyclo-butane

- **Stereoisomerism :** It is a type of isomerism in which isomers have different arrangement of atoms in a three dimensional space. It can be classified into two types: geometrical and optical isomerism.

  Example :



Trans-2-butene



Cis-2-butene

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- **Geometrical isomerism :** It is exhibited by unsaturated hydrocarbons that shows the restricted rotation of carbon-carbon bond due to the presence of double bond in a molecule.
  pi bond formed between carbon atoms by side way overlapping of p-orbitals and oriented perpendicular to sigma bond restricts the free rotation of carbon-carbon sigma bond and creates different configurations of a molecule. These configurations differ in the spatial arrangement of groups bonded to double bonded carbon atoms and are called as geometrical isomers of each other.
- These isomers cannot inter-convert into each other by free rotation of the carbon-carbon bond therefore, they can exist in two possible configurations: one in which similar groups placed on the same side cis isomers and another has similar groups on opposite sides known as trans isomer.
- For example, 2-butene exhibits cis-trans isomerism. In cis-isomer, both methyl groups are placed on the same side while in trans-isomer, methyl groups are placed on opposite sides.

cis– 2- butane

trans- 2-butene

- Hence, for geometrical isomerism, there must be a double bond in the molecule and the two atoms or groups bonded on double bonded atoms should be different. Alkenes with general formula: abC = Cab, abC = Ccd, abC = Cax exhibit geometrical isomerism. The compounds like aaC = Cab or aaC = Cbb cannot show this isomerism.
- **Cis-isomers v/s trans-isomers:** Cis-trans isomers show different physical properties like melting point, boiling point, dipole moment, solubility, etc. Cis-isomers are more polar compared to trans-isomers because individual dipole does not cancel each other. For example, the dipole moment of cis-2-butene is 0.33 D whereas that of trans-isomer is almost zero. Due to polarity, cis-isomers have a higher boiling point than trans-isomers, but the melting point of trans-isomers is more than that of cis-isomers due to their symmetrical nature.

Some common examples of cis-trans isomers :

- Maleic acid(cis-isomer) and fumaric acid (trans-isomer)
- Cis-1,2-Dichlorocyclohexane and trans-1,2-Dichlorocyclohexane
- Cis-1,2-Dichlorocyclopentane and trans-1,2-Dichlorocyclopentane
- Cis-1,2-Dicarboxycyclopropane and trans-1,2-Dicarboxy-cyclopropane
- Cis-2-Pentene and trans-2-Pentene
- Cis-1,2-Dichloroethene and trans-1,2-Dichloroethene
- Oleic acid (cis-isomer) and Elaidic acid (trans-isomer)
- Cis-2,3-Dichlorobut-2-ene and trans-2,3-Dichlorobut-2-ene

Coordination compounds can also show cis-trans isomerism due to different possible geometrical arrangements of ligands in heteroleptic complexes. Square planer and octahedral complexes show this type of isomerism. Some examples of cis-trans isomers are platinum amine complex

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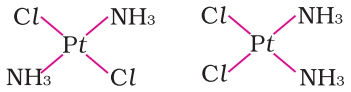
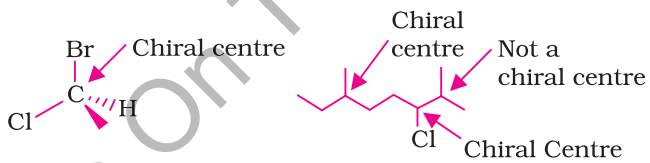


trans –$Pt(NH_3)_2Cl_2$ **cis –$Pt(NH_3)_2Cl_2$**

- **Optical Isomerism :** When plane polarized light is passed through the liquid or dissolved forms of certain substances, the light emerging out does not oscillate in the same plane. The plane of oscillation gets rotated through some angle towards the left or right of the original plane of oscillation.
- The substance which can rotate the plane of polarized light is known as an optically active substance.
- The substance which rotates the plane in clockwise direction, towards the right is known as dextro rotatory substance.This is indicated by putting letter d or (+) sign before the name of the substance. The substances which rotate the plane towards the left, *i.e.* in anticlockwise direction are known as levo rotatory substances and are indicated by putting l or (-) before the name of the substance.
- For a molecule to be optically active, there must be chiral carbon atom in the molecule and no plane of symmetry.
- **Chiral carbon atom :** A carbon atom bonded with four different atoms or groups in a molecule is called as chiral carbon atom or chirality center or asymmetrical carbon or stereocenter. For example, center carbon atom of lactic acid is chiral in nature and indicated with an asterisk (*). Similarly, amino acid molecules are also chiral due to chiral carbon atom.



- Chiral molecules are non-superimposable on their mirror image. The stereoisomerism related to each other as non-superimposable mirror is known as enantiomer. The enantiomer rotates the plane polarized light through the same angle but in the opposite direction. Thus, if one enantiomer is dextrorotatory, the other one will be levorotatory. Enantiomers show the same physical and chemical properties but different optical properties.
- **Coordination Isomerism :** In coordination compounds, if both the cation and anion are complex, they can show coordination isomerism. Coordination isomers differ in the distribution of ligands in cation and anion. Hence, this type of isomerism is because of the interchange of ligands between two complex ions. For example, tetraamminezinc(II) tetrachlorocuprate(II) and tetraaminecopper(II) tetrachlorozincate(II) are coordination isomers, as both are inter-convertible into each other by the interchange of ligands in cation and anion.

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$[Zn(NH_3)_4]^{+2}\ [CuCl_4]^{-2}$ $\boxed{[Cu(NH_3)_4]^{+2}\ [ZnCl_4]^{-2}}$

Tetraamine Zinc (II) Tetraamine Copper (II)
Tetraamine Cuprate (II) Tetraamine Zincate (II)

- **General methods of preparation of alkanes:** There are several methods of preparing alkanes. These include:
- Decarboxylation: The method involves the removal of CO_2 from the molecules having -COOH group. Saturated monocarboxylic acid salt of sodium or potassium on dry distillation with soda lime gives alkane.

$$RCOONa \xrightarrow[-CO_2]{Soda\ Lime} R-H$$

- The alkane formed by decarboxylation process always contains one carbon atom less than the original acid. The yield is good in case of lower members but poor for higher members.

$$CH_3COONa + NaOH \xrightarrow{CaO} CH_4 + Na_2CO_3$$

- Wurtz's reaction: It involves heating a solution of alkyl halide in ether with sodium gives alkane.

$$CH_3X + Na + C_2H_5X \rightarrow CH_3CH_3 + 2NaX$$

- Wurtz's reaction is not suitable for the synthesis of alkanes containing an odd number of carbon atoms.

Limitations of Wurtz reaction :

a. Methane cannot be obtained by this method.
b. The reaction fails in case of tertiary halides.

- **Reduction of alkyl halides:** Alkyl halides on reduction with nascent hydrogen form alkanes.

$$R\text{-}X + 2[H]' — R\text{-}H + HX.$$

- Alkyl halides can also be reduced catalytically to alkane by H_2/Pd or $LiAlH_4$ or by H_2/Ni. The yields are generally high and the hydrocarbons formed are pure.
- Reduction of alcohols, aldehydes, ketones or fatty acids and their derivatives in the presence of red P & HI gives corresponding alkane.
- Hydrogenation of alkenes((>C=C<) : Sabatier and Senderen's method
  Alkenes and alkynes on catatlytic hydrogenation give alkanes

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni,\ 200°C} CH_3\text{-}CH_3$$

$$CHa"CH + 2H_2 \xrightarrow{Ni,\ 200°C} CH_3\text{-}CH_3$$

- Catalyst Ni is used in finely divided form. If Pt or Pd is used as catalyst, reaction occurs at normal temperature. Also, sometimes Raney nickel is used as catalyst.
  Raney nickel is obtained by boiling Ni-AI alloy with NaOH, when AI dissolves leaving Ni in finely divided state. The filtered, washed and dried Ni is known as Raney Nickel. Raney Ni is effective at room temperature and atmospheric pressure.
- **Kolbe's electrolysis method:** Alkanes are formed, on the electrolysis of the concentrated aqueous solution of sodium or potassium salt of saturated mono carboxylic acids

$$RCOONa\ (aq) \xrightarrow{electrolysis} R-R + 2CO_2 + 2NaOH + H_2$$

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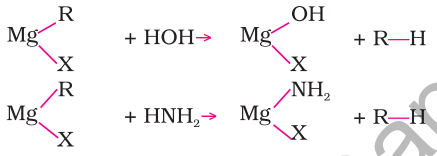
- Electrolysis of an acid salt gives symmetrical alkane. However, in case of the mixture of the carboxylic acid salts, all probable alkanes are formed.

$$R^1COOK + R^2COOK \xrightarrow{electrolysis} R^1\text{-}R^2 + 2CO_2 + H_2 + 2KOH$$

(R^1-R^1 and R^2-R^2 are also formed).

- **By Grignard reagents :** Organic compounds in which a metal atom is directly linked to carbon atom are known as organometallic compound. e.g., HCCNa $(C_2H_5)_4$ Pb, $(C_2H_5)_2$ Zn
- Alkyl or aryl magnesium halide (R-MgX) is also called Grignard reagent or organometallic compound.Grignard reagent on double decomposition with water or with other compounds having active H(the hydrogen attached on O, N, F or triple bonded carbon atom is known as active hydrogen) gives alkane.

e.g.



- **Reduction of Carbonyl compounds :** The reduction of carbonyl compounds by amalgamated zinc and conc. HCl also yields alkanes. This is **Clemmensen reduction.**

$$CH_3CHO + 2H_2 \xrightarrow{Zn+Hg/HCl} CH_3CH_3 + H_2O$$

$$CH_3CH_2COOH + 2H_2 \xrightarrow{Zn+Hg/HCl} CH_3CH_2CH_2CH_3 + H_2O$$

- Carbonyl compounds may also be reduced to alkanes by Wolf Kishner reaction

$$>C=O + H_2NNH_2 \rightarrow >C=NNH_2 \rightarrow \xrightarrow[180°C]{C_2H_5OH/Na} >CH_2 + NH_2NH_2$$

- **Hydrolysis of Al or Be carbides** : Only methane can be obtained by the hydrolysis of Be or Al carbides.

$$Al_4C_3 + 12H_2O \xrightarrow{\Delta} 4Al(OH)_3 + 3CH_4$$

$$Be_2C + 4H_2O \xrightarrow{\Delta} 2Be(OH)_2 + CH_4$$

- CH_4 can be obtained by passing a mixture of H_2S and CS_2 through red and Cu tube

$$CS_2 + 2H_2S \xrightarrow{cu} CH_4 + 4Cu_2S$$

- **Hydroboration of alkenes :** Alkenes on hydroboration give trialkyl borane as a result of the addition of diborane on olefinic bond. This trialkyl borane on treatment with acetic acid or propanoic acid yields alkane.

$$2R\text{-}CH=CH_2 \xrightarrow{B_2H_6} 2(RCH_2CH_2)3B \xrightarrow{CH_3COOH} 2RCH_2CH_3$$

- **Corey-House synthesis :** Alkyl chloride such as chloroethane reacts with lithium in presence of ether to give lithium alkyl which then reacts with CuI to give lithium dialkyl cuprate. This lithium dialkyl cuprate now again reacts with alkyl chloride to give alkane.

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$$CH_3CH_2CI + 2Li \xrightarrow{Ether} CH_3CH_2Li + LiCl$$
$$2CH_3CH_2Li + CuI \rightarrow Li(CH_3CH_2)_2\ Cu + LiL$$
$$Li\ (CH_3CH_2)_2Cu + CH_3CH_2CI \rightarrow CH_3CH_2CH_2CH_3 + CH_3CH_2Cu + LiC$$

- **Properties of alkanes :** Alkane molecules are non-polar and, therefore, generally do not react with ionic compounds such as most laboratory acids, bases, oxidizing agents or reducing agents.
- Neither positive ions nor negative ions are attracted to a non-polar molecules. In fact, the alkanes undergo so few reactions that they are sometimes called paraffins, from the Latin parum affinis, meaning "little affinity".
- Two important reactions that the alkanes do undergo are combustion and halogenation. Nothing happens when alkanes are merely mixed with oxygen (O_2) at room temperature, but when a flame or spark provides the activation energy, a highly exothermic combustion reaction proceeds vigorously. For methane (CH_4), the reaction is as follows:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + heat$$

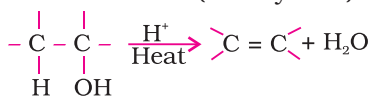
- If the reactants are adequately mixed and there is sufficient oxygen, the only products are carbon dioxide (CO_2), water (H_2O), and heat. When the oxygen supply is limited, carbon monoxide (CO) is a by-product:

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

- Alkanes react with the halogens chlorine (Cl_2) and bromine (Br_2) in the presence of ultraviolet light or at high temperatures to yield chlorinated and brominated alkanes. For example, chlorine reacts with excess methane (CH_4) to give methyl chloride (CH_3Cl).

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

- With more chlorine, a mixture of products is obtained: CH_3Cl, CH_2Cl_2, $CHCl_3$ and CCl_4.
- Fluorine (F_2), the lightest halogen, combines explosively with most hydrocarbons. Iodine (I_2) is relatively not reactive.
- **General methods for the preparation of alkenes :** There are several methods of preparing alkanes. These include:
- **Dehydration of alcohols :** Heating alcohols is a general method of the preparation of alkenes. Heating alcohols with a strong acid causes them to lose a molecule of water (to dehydrate) and form an alkene.



- The reaction is an elimination and is favoured at higher temperatures. The most commonly used acids in the laboratory are Bronsted acids, proton donors such as sulphuric acid and phosphoric acid.
- Dehydration reactions of alcohols show several important characteristics which can be explained as :
- Dehydration of ethanol, for example, requires concentrated sulphuric acid and a temperature of 180°C.

$$CH_3CH_2OH \xrightarrow{\text{Warm Conc.}H_2SO_4} H_2C = CH_2 + H_2O$$

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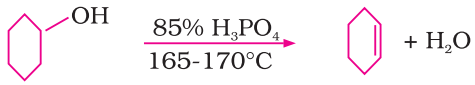
- Secondary alcohols usually dehydrate under milder conditions. Cyclohexanol, for example, dehydrates in 85% phosphoric acid at 165-170°C.



- Tertiary alcohols are usually so easily dehydrated that extremely mild conditions can be used. Ter-butyl alcohol, for example, dehydrates in 25% H_2SO_4 at a temperature of 85°C.

$$CH_3-\underset{CH_3}{\overset{CH_3}{C}}-OH \xrightarrow[85^\circ\ C]{20\%\ H_2SO_4} CH_3-\overset{CH_3}{C}=CH_2+H_2O$$

- Thus, overall, the relative ease with which alcohols undergo dehydration is in the following order
- Ease of Dehydration: 3° Alcohol > 2° Alcohol > 1° Alcohol.

Dehydrohalogenation of monohalides :

(a) Removal of HX from a substrate by alcoholic KOH or $NaNH_2$.

(b) $\underset{X}{CH_3CH_2CHCH_3} \xrightarrow{Zn\ dust} \underset{\text{Major}}{CH_3CH=CHCH_3} + \underset{\text{Minor}}{CH_3CH_2CH=CH_2}$

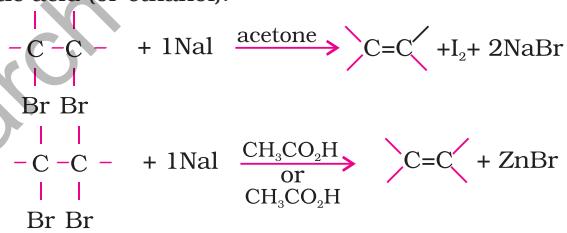
(Saytzeff rule)

(c) The case of dehydrohalogenation shows the order:

For alkyl halides: tertiary > secondary > primary alkyl halides

For halogens in halides : iodide > bromide > chloride

- **Dehalogenations of dihalides :** Vicinal (or vic) dihalides are dihalo compounds in which the halogens are situated on adjacent carbon atoms. The name geminal (or gem) dihalide is used for those dihalides where both halogen atoms are attached to the same carbon atom. Vic-dibromides undergo debromination when they are treated with a solution of sodium iodide in acetone or a mixture of Zn dust in acetic acid (or ethanol).



- Debromination by sodium iodide takes place by an E2 mechanism similar to that for dehydrohalogenation.
- **Kolbe's electrolysis :** Electrolysis of the aqueous solutions of sodium or potassium salts of saturated dicarboxylic acids gives alkene at anode along with carbon dioxide.
- **Partial hydrogenation of alkynes :** Hydrogenation of alkynes in the presence of Lindlar catalyst gives alkenes.

$$HC\equiv CH \xrightarrow[\textit{Lindlar catalyst}]{H_2,\ \Delta} H_2C=CH_2$$

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- Lindlar catalyst is Pd on $CaCO_3$ deactivated by lead acetate which prevents further hydrogenation.

By heating quaternary ammonium compounds:

$$(C_2H_6)_4N^+OH^- \xrightarrow{\Delta} (C_2H_6)_3N + C_2H_4 + H_2O$$

Tetraethyl ammonium hydroxide → tertiary ethylamine

By Grignard reagents :

$$Mg\begin{matrix}/R\\ \backslash R\end{matrix} + XCH = CH_2 \rightarrow RCH = CH_2 + MgX_2$$

- Action of Copper alkyl on Vinyl Chlorides : Vinyl chloride on alkylation with copper alkyl forms higher alkenes.

$$2H_2C = CHCl \xrightarrow{R_2Cu} 2H_2C{=}CHR + CuCl_2$$

$$2H_2C = CHCl \xrightarrow{(CH_2)_2\,Cu} 2H_2C{=}CHR + CuCl_2$$

- **Chemical properties of alkenes :** Alkenes are more reactive than alkanes due to the presence of a double bond. The carbon-carbon double bond consists of a strong bond and a weak pi bond. The typical reactions of alkenes involve the breaking of this weaker pi bond, viz. and formation of two sigma (s) bonds.

- Such reactions are called addition reactions and are initiated by an electrophile, proceeding through ionic mechanism. However, some addition reactions proceed through free-radical mechanism.
- **Combustion :** Alkenes, like alkanes, are highly combustible. They burn with a luminous flame to give carbon dioxide and water. The flame becomes luminous because of the higher carbon content of alkenes than alkanes. Their combustion reactions are exothermic.

$$CnH_2n + \frac{3n}{2}O_2(g) \longrightarrow nCO_2 + nH_2O + \text{Heat}$$

- Due to the luminosity of the flame, the lower alkenes may be used as illuminants.
- **Addition reactions :** The p–electrons of the carbon-carbon-double bond are available to an electrophile (any species seeking electrons). Thus, the addition reactions shown by alkenes are, in fact, electrophilic addition reactions.
- Some addition reactions proceed through free-radical mechanism.
- **Addition of hydrogen :** Alkenes add hydrogen in the presence of platinum or nickel catalyst, to form alkanes. The reaction termed as hydrogenation, is an exothermic reaction.

$$C_nH_{2n} + H_2 \xrightarrow{\text{Ni, } 200°C} CnH_{2n+2} + \text{heat}$$

- This is known as Sabatier-Senderens reduction.

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni} CH_3\text{-}CH_3 + 132.2\ kJ$$

- **Addition of halogens :** Alkenes react with halogens to form dihaloalkanes. The order of reactivity is, chlorine > bromine > iodine.

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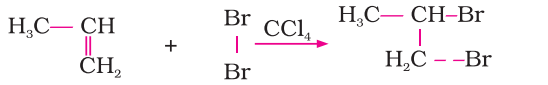
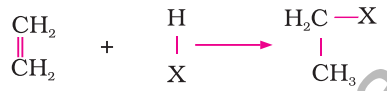
Simply mixing together the two reactants, usually in an inert solvent like carbon tetrachloride, best carries out the reaction.



propene Bromoethane

- Addition of bromine is useful for the detection of the carbon-carbon double bond. When a 5% solution of bromine in carbon tetrachloride is added to an alkene, it gets decolourized. This indicates the presence of a double bond in the molecule. This test is called 'bromine test'.
- **Addition of halogen acids :** Alkenes with the concentrated aqueous solution of halogen acids give haloalkanes. The order of reactivity is,HI > HBr > HCl , e.g.,

  Ethene gives



Ethene haloethane

$H_3C–CH=CH–CH_3$ + HBr $\rightarrow H_3C–CH_2–CH(Br)–CH_3$

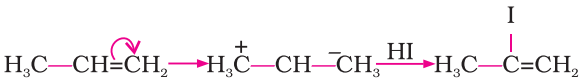
2-Butene 2-bromobutane

- Symmetrical alkenes give only one product, due to the equivalence of the two carbon atoms (H and X may add to the molecule in any way). In asymmetrical alkenes, the addition of a halogen acid takes place in a manner whereby the halogen atom (the negative part of the molecule to be added) adds to the carbon atom, which has lesser number of hydrogen atoms on it. For example, in the case of propene, the product obtained is 2-iodopropane and not 1-iodopropane.

  $CH_3– CH = CH_2 + HI \rightarrow CH_3 – CH(I) – CH_3 + I_2$

  2-iodopropane

- The I being negative part of the added molecule, goes to the carbon number 2 because it has only one H-atom on it. (lesser number of H-atom). This rule of the addition of halogen acids to an asymmetrical alkene is known as Markownikoff's rule.
- **Markownikoff's rule :** This is an empirical rule according to which the addition occurs by a polar mechanism, e.g., the addition of HI to propylene. Since a methyl group is electron-repelling, the propylene molecule is polarized as follows.



prop-1-ene2-iodopropane

- Hence, the proton of the hydroiodic acid gets attached to the negatively charged carbon and the iodide ion to the positive carbon.

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- **Peroxide effect :** The mode of addition of hydrogen bromide to unsymmetrical alkenes in the presence of oxygen and peroxides is contrary to Markownikoff's rule. This addition of HBr to unsymmetrical alkenes against the Markownikoff's rule is known as peroxide effect, or anti-Markownikoff's rule.
- For instance, the reaction of propene with HBr in the presence of peroxides, forms 1-bromopropane instead of 2-brompropane.

$$\underset{\text{Propene}}{CH_3\text{-}CH{=}CH_2} + HBr \longrightarrow \underset{\text{1 -Bromopropane}}{CH_3\text{-}CH_2\text{-}CH_2Br}$$

- The mode of the addition of hydrogen chloride or hydrogen iodide is not affected by the presence of peroxides.
- **Addition of sulphuric acid :** In accordance with Markownikoff's rule, alkenes readily add concentrated sulphuric acid to form alkyl hydrogen sulphates, e.g., ethene gives,

$C_2H_4 + H_2SO_4 \rightarrow C_2H_2SO_4(OH)$

$$\underset{\text{Ethene}}{\begin{matrix} CH_2 \\ \| \\ CH_2 \end{matrix}} + \underset{\text{Sulphuric acid}}{\begin{matrix} H \\ | \\ OSO_2.OH \end{matrix}} \longrightarrow \underset{\text{Ethyl hydrogen sulphate}}{\begin{matrix} CH_2.O.SO_2OH \\ | \\ CH_3 \end{matrix}}$$

- An alkyl hydrogen sulphate on boiling with water gives alcohol and sulphuric acid. Alcohols are prepared from alkenes obtained from the cracking of petroleum. For example,

$$\underset{\text{ethyl hydrogen sulphate}}{\begin{matrix} CH_2.O.SO_2OH \\ | \\ CH_3 \end{matrix}} + H_2O \xrightarrow{\text{heat}} \underset{\text{ethanol}}{\begin{matrix} H_2C\text{—}OH \\ | \\ CH_3 \end{matrix}} + H_2SO_4$$

- **Addition of hypohalous acids :** Hypohalous acid (HOX) in accordance with the Markownikoff's rule, adds to the molecule of an alkene at the double bond, e.g.

$$\underset{\text{propene}}{H_3C\text{–}CH{=}CH_2} + HOCl \longrightarrow \underset{\text{1-chloro-2-propanol propylene (chlorohydrin)}}{H_3C\text{–}\underset{OH}{\underset{|}{CH}}\text{–}\underset{Cl}{\underset{|}{CH_2}}}$$

- **Hydration of alkenes :** Water molecule adds to an alkene molecule across the double bond in the presence of dilute acids and a catalyst, e.g., ethane gives ethanol when a mixture of ethene and steam is passed over phosphoric acid and silica under a pressure 65 atm, and at 300C.

$$\begin{matrix} CH_2 \\ \| \\ CH_2 \end{matrix} + H_2O \xrightarrow[300°C,\ 65\ atm]{H_3PO_4} \begin{matrix} CH3 \\ | \\ CH2\ –OH \end{matrix}$$

- **Addition of oxygen :** Lower alkenes are mixed with air and passed under pressure over a silver catalyst at 200-400°C. This gives

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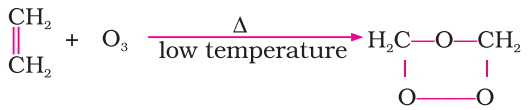
epoxides by adding one atom of oxygen across the double bond. The epoxides so obtained are used in detergents.

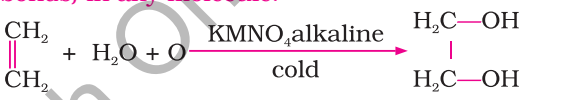
ethene ethene epoxide

- **Addition of ozone :** Ozonides are formed when alkenes add with a molecule of ozone across the double bond. For example, ethene gives ethene ozonide.



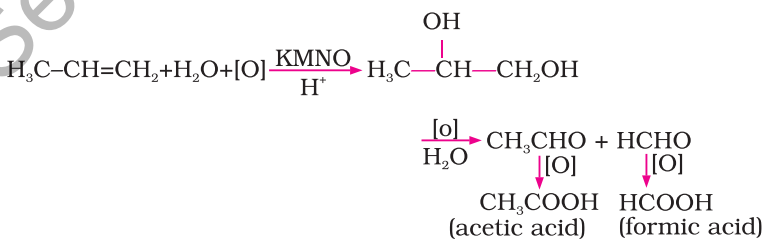
ethene ethene ozonide

- Ozonides on hydrolysis with water in the presence of a reducing agent give aldehydes.
- The oxidation of alkenes by ozone followed by the decomposition of the formed ozonide with water, is termed as 'ozonolysis'. The nature of the products (aldehydes and ketones) formed due to ozonolysis depends upon the location of the double bond in the parent alkene. Therefore, this reaction provides a very convenient way of locating the position of the double bond in any molecule.
- **Oxidation :** Alkenes can be readily oxidized, but the nature of the products depends upon the oxidizing agent used.
- **With cold, alkaline $KMnO_4$:** When alkenes are oxidised with cold, alkaline $KMnO_4$, dihydroxy compounds (diols or glycols) are formed. The $KMnO_4$ gets decolourized. This reaction is, therefore, used as Bayer's test for unsaturation (the presence of double or triple bonds) in any molecule.



ethene ethane-1,2-diol

- **With acidified KMnO4 Or K2Cr2O7 :** Acidified potassium permanganate (or potassium dichromate) oxidises the dihydroxy compound so produced in reaction to ketone and/or carboxylic acid, e.g.,



- **Substitution reactions :** At high temperatures (500°C), higher alkenes give substitution products with chlorine e.g.

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$$CH_3\text{-}CH{=}CH_2 + Cl_2 \xrightarrow{500°C} ClCH_2\text{-}CH{=}CH_2 + HCl$$

Propene → 3-chloropropene

- Branched-chain alkenes give substitution reaction easily. For example, isobutene gives substitution product with chlorine even at room temperature.

$$CH_3\text{–}\underset{\underset{CH_3}{|}}{C}{=}CH_2 + Cl_2 \longrightarrow ClCH_2\text{–}\underset{\underset{CH_3}{|}}{C}{=}CH_2 + CHl$$

isobutene → 3-chloro-2-methylpropene

- **Polymerization :** Polymerization can be additional or condensational. Addition polymerization is a process by which a large number of molecules of the same species join together (without the elimination of simple molecules like HX, H_2O, etc.) to form a giant molecule, called a polymer. Alkenes undergo addition polymerization when heated under pressure, in the presence of suitable catalysts. When ethene is heated to 100°C under 1000 atm pressure in presence of oxygen, we get polyethene

$$nCH_2{=}CH_2 \xrightarrow[\text{(trace)}]{O_2} \text{–(– } CH_2\text{– } CH_2\text{–)}_n\text{–}$$

ethene → polythene

- Similarly, when vinyl chloride is polymerized in the presence of peroxide catalyst, it forms polyvinyl chloride (PVC).

$$nCH_2{=}CH_2 \xrightarrow[\text{(trace)}]{O_2} \text{—(—}CH_2\text{–}CH_2\text{—)n—}$$

ethene → polyethene

Teflon is a polymer of tetrafluoroethene,

$$nCF_2{=}CF_2 \longrightarrow \text{–(–}CF_2\text{–}CF_2\text{–)}_n\text{–}$$

tetrafluoroethene → teflon

Isomerization

- Alkenes when heated alone at high temperatures (500-700°C) or at lower temperatures (200-300°C) isomerize in the presence of catalyst, such as $Al_2(SO_4)_3$. Alkene isomerism occurs due to the shifting of the double bond which tends to move towards the centre of chain, e.g., pentene-1 isomerizes to pentene-2.

$$CH_3\text{–}CH_2\text{–}CH_2\text{–}CH{=}CH_2 \longrightarrow CH_3\text{– } CH_2\text{– } CH{=} CH \text{ – } CH_3$$

pentene-1 → pentene-2

- **Preparation of alkynes:** Acetylene itself is formed from the reaction of the inorganic compound calcium carbide with water.

$$CaC_2 + 2\ H_2O \rightarrow Ca(OH)_2 + HCa \equiv CH$$

- This method was once an important industrial process for the manufacture of acetylene. However, the method has now been replaced by a process in which methane is pyrolyzed in a flow system with short contact time.

$$2CH_4 \xrightarrow[0.01\text{–}0.1\ \text{sec.}]{1500°C} HC \equiv CH + 3H_2$$

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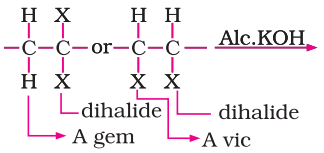
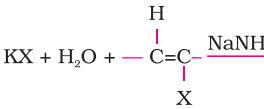
- This reaction is endothermic at ordinary temperatures, but is thermodynamically favoured at high temperatures.
- **Laboratory Methods for the Preparation of Alkynes**: These methods include:

Dehydrohalogenation of vic-Dihalides or gem-Dihalides





A vinyl halide

Dehalogenation of vic-Tetrahalogen Compounds

$$CH_3–CBr_2–CBr_2–CH_3 + 2Zn \xrightarrow[\text{heat}]{\text{FtOH}} CH_3–C\equiv C–CH_3 + 2ZnBr_2$$

2, 2,3,3-Tetrabromobutane 2-butyne

- This reaction has the drawback that the halogen compound is itself prepared by halogen addition to alkynes.

Alkyl Substitution in Acetylene: Acidity of ≡ C–H

$$R–C\equiv C–H + \left\{\begin{matrix} NaNH_2 \\ \text{or} \\ Na \end{matrix}\right. \longrightarrow R–C\equiv C : Na^+ + \left\{\begin{matrix} NH_3 \\ \text{or} \\ \frac{1}{2}H_2 \end{matrix}\right.$$

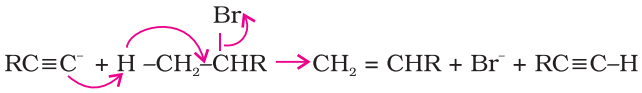
- There is a fair amount of variety possible using this method. Acetylene itself may be alkylated either once to make a terminal alkyne or twice to make an internal alkyne.

$$HC\equiv CH + HaNH^2 \xrightarrow[-33°C]{\text{liq.}NH_3} HC\ CNa^+ \xrightarrow{n\text{-}C_4H_9Br} CH_3(CH_2)_3C\equiv CH$$

1-hexyne

$$HC\equiv CH \xrightarrow[\text{liq.}NH_3]{2NaNH_2} 2n + C_3H\text{-}Br$$

- Since acetylide ions are highly basic, competing elimination is a common side-reaction.
- The products of such an elimination reaction are an alkene (from the alkyl halide) and an alkyne.



- In practice, the alkylation of acetylene or another terminal alkyne is only a good method for the synthesis of alkynes when applied

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to primary halides that do not have branches close to the reaction centre. With secondary halides, and even with primary halides that have branches close to the reaction centre, elimination is usually the major reaction.

Industrial Method for preparation of alkynes:

- **Preparation of higher alkynes :** Higher alkynes may be obtained by acetylene.

$$CHa \equiv CH + Na \xrightarrow{liq\ NH_s} CHa{\equiv}CNa + 1/2H_2$$

$$CHa{\equiv}CNa + RX \rightarrow CHa{\equiv}CR + NaX$$

$$CHa{\equiv}CH + RMgX \rightarrow XMg\text{-}Ca{\equiv}CH \rightarrow R\text{-}Ca{\equiv}CH + MgX_2$$

Other General Methods of the Preparation of Alkynes include:

By Haloform : Only for acetylene

$$CHX_3 + 6Ag + X_3HC \xrightarrow{heat} CHa \equiv CH + 6AgX$$

By Kolbe's electrolytic method :

$$\begin{matrix} CHOOK \\ \| \\ CHX_{(aq)} \end{matrix} \xrightarrow{\text{Electrolysis}} \underset{\text{Anode}}{CH{\equiv}CH + 2CO_2} + \underset{\text{Cathode}}{2KOH + H_2}$$

Pot. fumarate or malate

- **Properties of Alkynes :** There are a number of alkyne chemical properties. Some of these include:
- **Combustion :** Alkynes burn in air or oxygen with smoky flame.

$$C_nH_{2n}{-}2 + \frac{(3n - 1)}{2} O_2 \rightarrow n\,CO_2 + (n{-}1)H_2O$$

- **Electrophilic Addition Reactions :** Carbon-carbon triple bond, C °C, is a combination of one and two bonds. Alkynes give electrophilic addition reactions as they show reactivity due to the presence of bonds. This property is similar to alkenes but alkynes are less reactive than alkenes towards electrophilic addition reactions due to the compact CC electron cloud. Some typical electrophilic addition reactions given by alkynes are:
- **Addition of hydrogen** : An alkyne reacts with hydrogen in the presence of catalyst (Pt or Ni) at 250°C, first forming alkenes and finally alkane.

$$\underset{\text{alkyne}}{R{-}C{\equiv}CH} \xrightarrow[pt/Ni]{+H_2} \underset{\text{alkyne}}{R{-}CH{=}CH_2} \xrightarrow[pt/Ni]{+H_2} \underset{\text{alkyne}}{R{-}CH_2{-}CH_3}$$

For example, ethyne gives ethane in two steps.

$$\underset{\text{ethyne}}{\begin{matrix} CH \\ \| \\ CH \end{matrix}} + H_2 \xrightarrow{Ni} \underset{\text{ethene}}{\begin{matrix} CH_2 \\ \| \\ CH_2 \end{matrix}} + H_2 \xrightarrow{N2/Ni} \underset{\text{ethane}}{\begin{matrix} CH_3 \\ | \\ CH_3 \end{matrix}}$$

- Ethane is obtained in good yield if hydrogenation is done with a calculated amount of hydrogen in the presence of palladium or barium sulphate.

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- **Addition of Halogens :** Alkynes react with halogens (Cl_2 or Br_2) in the dark, forming dihaloalkenes first and finally tetrahaloalkanes. The reaction gets accelerated in the presence of light or halogen carriers.

$$\underset{\text{Alkyne}}{RC{\equiv}CH} \xrightarrow{+X_{21}} \underset{\text{dihaloalkene}}{RCX{=}CHX} \xrightarrow{+X_{21}} \underset{\text{tetrahaloalkane}}{RCX_2CX_2}$$

For example, ethyne (acetylene) with chlorine gives,

$$\underset{\text{ethyne}}{\begin{matrix}CH\\|||\\CH\end{matrix}} + Cl_2 \longrightarrow \underset{\text{dihaloalkene}}{\begin{matrix}CHCl\\||\\CHCl\end{matrix}} \xrightarrow{+Cl_2} \underset{\text{tetrahaloalkane}}{\begin{matrix}CHCl_2\\|\\CHCl_2\end{matrix}}$$

Dilute bromine water propyne gives,

$$\underset{\text{propyne}}{CH_3{-}C{\equiv}CH} \xrightarrow{+Br_2} \underset{\text{1,2-dibromo propene}}{CH_3{-}\underset{Br}{C}{=}CHBr} \xrightarrow{+Br_2} \underset{\text{1,1,2,2-tetrabromopropane}}{CH_3{-}\underset{Br}{\overset{Br}{C}}{-}\underset{Br}{\overset{Br}{C}}{-}CH}$$

The order of reactivity is $Cl_2 > Br_2 > I_2$.

- **Addition of Halogen Acids :** Alkynes react with halogen acids according to the Markownikoff's rule, *i.e.* the carbon atom carrying the least number of hydrogen atoms will have the negative part of the addendum attached to it. For example, ethyne (acetylene) with HBr gives,

$$\underset{\substack{\text{ethyne}\\\text{(acetylene}}}{\begin{matrix}C\\|||\\CH\end{matrix}} + HBr \longrightarrow \underset{\substack{\text{bromoethene}\\\text{(vinyl bromide)}}}{\begin{matrix}CBr\\||\\CH_2\end{matrix}} \xrightarrow{+HBr} \underset{\substack{\text{1,1-dibromoethane}\\\text{(ethylidene dibromide)}}}{\begin{matrix}CBr_2\\|\\CH_3\end{matrix}}$$

- With diluted HCl at 65°C and in the presence of Hg^{2+} (mercuric ion) ethyne gives vinyl chloride.

$$\begin{matrix}CH\\|||\\CH\end{matrix} + HCl \xrightarrow{65°C,\ Hg^{2+}} \begin{matrix}CHCl\\||\\CH_2\end{matrix}$$

Propyne gives

$$\underset{\text{propyne}}{\begin{matrix}H_3C{-}C\\|||\\CH\end{matrix}} + HBr \longrightarrow \underset{\text{2-bromopropene}}{\begin{matrix}H_3C{-}CBr\\||\\CH_2\end{matrix}} \xrightarrow{+HBr} \underset{\text{2,2 -dibromopropane}}{\begin{matrix}H_3C{-}CBr_2\\|\\CH_3\end{matrix}}$$

- The rate of the addition of halogen acids follows the order, HI > HBr > HCl
- **Substitution Reactions :** Alkynes because of their acidic nature form metallic salts called alkynides, e.g., sodium, silver and

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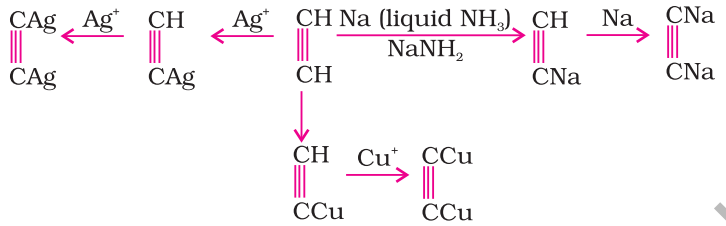
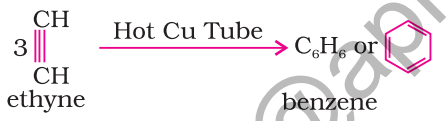
copper(ous) salt, e.g., ethyne (acetylene) has two acidic hydrogen atoms, hence, it finally gives dimetal salts.

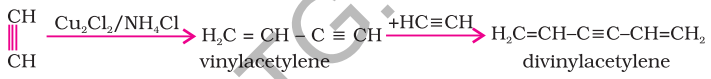


dicopper acetylide (red precipitate)

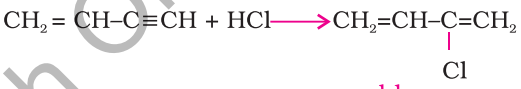
- **Polymerisation :** On heating, alkynes undergo polymerisation in the presence of catalyst. The nature of products depends upon the conditions, e.g:
- When ethyne (acetylene) is passed through a hot copper tube, it polymerizes to benzene.



- When passed through a solution of cuprous chloride in ammonium chloride, ethyne undergoes linear polymerization.



- Vinyl acetylene with hydrogen chloride gives chloroprene (2-chlorobuta-1,3-diene), which readily polymerizes to give neoprene (a synthetic rubber).



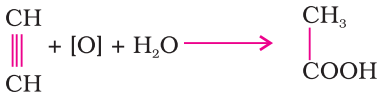
chloropropene
(2-chlorobuta-l, 3-diene)

- **Oxidation :** Oxidation of alkynes gives mono or dicarboxylic acids, e.g.,

Alkaline $KMnO_4$ oxidises ethyne to oxalic acid.

oxalic acid (ethanedioic acid)

With chromic acid, ethyne gives acetic acid.



Ethyne ethanoic acid (acetic acid)

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Benzene and substitution reactions			
Halogenation	$C_6H_6 + Cl_2$	$\xrightarrow[\text{Heat}]{FeCl_3}$	$C_6H_5Cl + HCl$
Nitration	$C_6H_6 + HNO_3$	$\xrightarrow[\text{Heat}]{H_2SO_4}$	$C_6H_5NO_2 + H_2O$
Sulphnation	$C_6H_6 + H_2SO_4 + SO_3$	$\xrightarrow{\Delta}$	$C_6H_5SO_3H + H_2O$
Alkylation	$C_6H_6 + R–Cl$	$\xrightarrow{Alcl_3, \Delta}$	$C_6H_5–R + HCl$
(Friedel crafts)			
Acylation (Friedal craft)	$C_6H_6 + RCOCl$	$\xrightarrow{Alcl_3, \Delta}$	$C_6H_5COR + HCl$

Polymerisation : It is the process of reacting monomer molecules together to form polymer chain. In chemical compounds, polymerization occurs via variety of reaction mechanisms that vary in complexity due to functional groups in reacting compounds and their inherent steric effect. A three dimensional network based on type of plastic formed by polymerisation is thermoplastic or thermosetting plastic. Thermo plastics are those that can be remoulded on heating like polyethylene, PVC (Polyvinyl chloride), poly propylene, PET, etc. Thermo setting plastics are those which cannot be remoulded after their heating such as bakelite, melanine, urea formaldehyde etc.

Rubber : Natural rubber not effective for commercial use. It is polymer of isoprene (2-methyl-1, 3-butadiene) extracted from latex collected from rubber tree. For commercial use natural rubber is heated with sulphur in process called the vulcanization to obtain vulcanized rubber. If isoprene is heated with chlorine the result is chloroprene, fire resistant rubber. The other types of rubber in use include :

- Styrene butadiene rubber (SRB) used for covering different hoses.
- Butadiene rubber (BR) mostly mixed with other rubber types to improve elasticity, wear resistance and low temperature properties.
- Neoprene polymer of chloroprene which is fire resistant with high tensile strength.

Ceramics : These are inorganic, non-metallic crystalline oxides, nitride or carbide materials prepared by their heating followed with subsequent cooling. These are used in making armoury, in electrical industry from insulator to resistor in semiconductor or high temperature super conductor like BSCCO based on element bismuth, strontium, calcium, copper and oxygen. In space shuttle ceramic tiles are used as thermal barriers.

White wares : These are ceramic products with colour from white to off white. They are produced from mixture of clay, flint and feldspar . They are characterized by their property of being unwetable, poor heat and electrical conductivity. They are impermeable to liquids and can be imparted into different shapes of different sizes such as in making flower vase, container for pickles etc.

Currently, there are thousands and thousands of polymers in use today for one reason or other. These include from the kitchen wares

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to water storage tanks to the products involved in production of bullet proof glass, jackets and parts of airplane and spacecrafts. The table below has the list of some of the common polymers in use.

Different type of polymers with uses		
Name	**Raw material**	**Uses**
Polyethylene	Ethylene	Insulating wires, making toys, flexible pipes, bottle containers like cans for storing liquid chemicals including water.
Polypropylene	Propylene	Making carpet fibres, seat covers, ropes, wraps for records and for packaging.
Polystyrene	Styrene	Making toys, hot drinking cups, combs, lining material for T.V. cabinet and refrigerators.
Poly methyl methacrylate (PMMA) or Perpex	Methyl methacrylate	Head transparent covering for the unbreakable lights, protective coating, aeroplane windows panes.
Teflon or polytetra theroethylene	Tetrafluro ethylene	Making seal to withstand high temperature and pressure, non-sticking surface of cooking vessels, insulation of high frequency electric installation.
PVS (Poly vinyl chloride)	Vinyl chloride	Insulation of electric cables, rain coats, table cloths, convey/or belts, etc.
Terylene	Ethylene glycol and terephthalic acid	Making magnetic recording tapes, aprons for industrial workers, blend in cloth etc.
Nylon-66	Adipic acid and Hexamethylene diamines	Milk bristles of tooth brush, sheets, climbing ropes, socks, sweater and jersey.
Nylon-6	Cyclohexane and	Tyre cords, ropes, fabrics.
Bakelite	O-hydroxymethyl phenol and P-hydroxymethyl phenol	Making of board, pens, formica table, taps and electrical switches.
Melamine	Melamine and formaldehyde	Making of unbreakable cups, glass sheets and plates.
Dextron	Glycolic acid lactic acid	Used as sutures after operation. These are self soluble in a week's time.

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UNIT-III

BIOLOGY

1. CYTOLOGY
2. TISSUES STRUCTURE AND FUNCTIONS
3. CLASSIFICATION OF PLANTS AND ANIMALS
4. PLANT STRUCTURE AND FUNCTIONS
5. PLANT PHYSIOLOGY
6. HUMAN PHYSIOLOGY
7. PLANT AND ANIMAL REPRODUCTION
8. HEREDITY AND VARIATION
9. EVOLUTION, INORGANIC AND ORGANIC EVOLUTION
10. BIOTECHNOLOGY PRINCIPLES AND APPLICATIONS
11. HUMAN HEALTH, DISEASES AND TREATMENT
12. PLANT PATHOLOGY
13. MICRO-ORGANISMS : FRIENDS TO MANKIND
14. ENVIRONMENT AND ECOLOGY
15. POLLUTION : CAUSES AND EFFECTS
16. AGRICULTURE & ANIMAL HUSBANDRY

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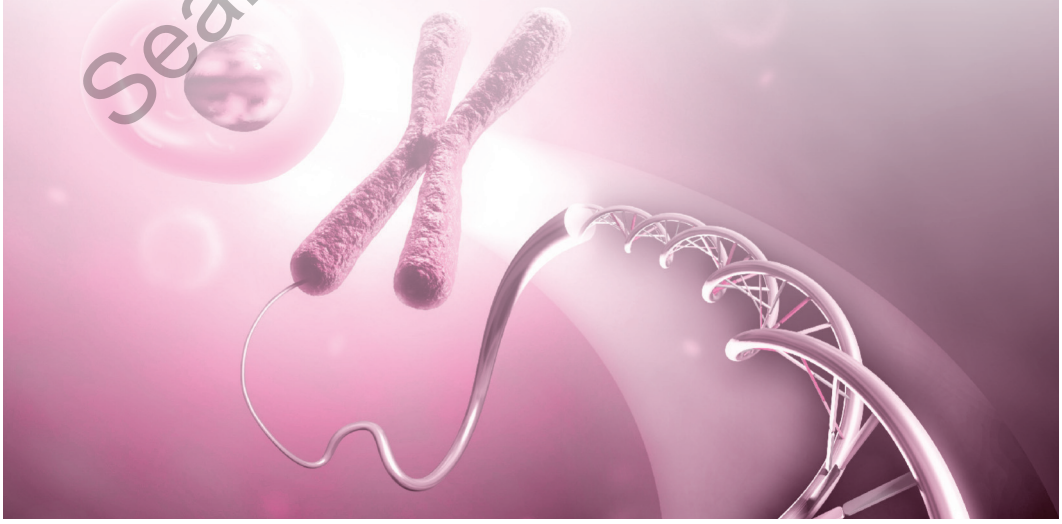

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Chapter 1

CYTOLOGY

Cell as structural and functional unit of life, cell organelles with their specific functions, types of cells, difference between prokaryotic and eukaryotic cells, difference between DNA and RNA.

- **Cytology :** It is also called cell biology which deals with the study of cell. Cell the structural and functional unit of life. It's merely because not only that all living organisms are made up of cell(s) but also all the functions by an organism are performed by the different parts of a cell called cell organelles.
- **Robert Hooke :** In 1665, observed the dead cells in a thin slice of cork as small compartment like-structures.
- **Anton Von Leeuwenhoek :** He observed bacteria, protozoa, etc in a drop of pond water. He called them "Animacule". He is also considered to be the first to use the simple microscope in his study. Hence, considered as pioneer of microscopy.
- **Cell theory :** It was proposed by M. Schleiden and T. Schwan. They defined a cell as the structural and functional unit of life. However, with the passage of time it got modified too-stating a cell also Eukaryotic cell, Prokaryotic cell to be the carrier of hereditary material.
- **Rudolf Virchow :** The statement "Ominis cellula de cellula" was proposed by him. It stated that every cell arises from the pre - existing cell.
- Structurally, a cell is described as a mass of protoplasm, invested with plasma membrane. However, all the known cells have broadly been classified as prokaryotic and eukaryotic cell (Doughherty).
- **Smallest and largest cell :** The smallest living cell is of PPLO (Pleuro pneumonia-like organism), a micoplasma gallisepticum and the largest is an ostrich's egg.
- **Longest plant and animal cell :** *Acetabularia* (Umbrella plant) is the longest plant cell about 10 cm in length and neuron is the longest animal cell.
- **Eukaryote :** When within a cell, in most of plants and animals, there are various membrane bound structures called cell organelles like mitochondria, chloroplast, nucleus, the cell is known as a **eukaryote**. Each cell organelle performs a specific function of the cell in a well-organized and coordinate manner.
- **Prokaryote :** In bacteria, mycoplasma and blue-green algae (Cyanobacteria), cells have no definite cell organelles and the nucleus *i.e.* nucleoplasm and cytoplasm are not separated.
- **Protoplasm :** It refers to the sum of the living matter present inside a living cell as proposed by Purkinjee. It is comprised of the nucleus and matrix cytoplasm carrying a number of embedded structures called cell organelles between nucleus and cell membrane.

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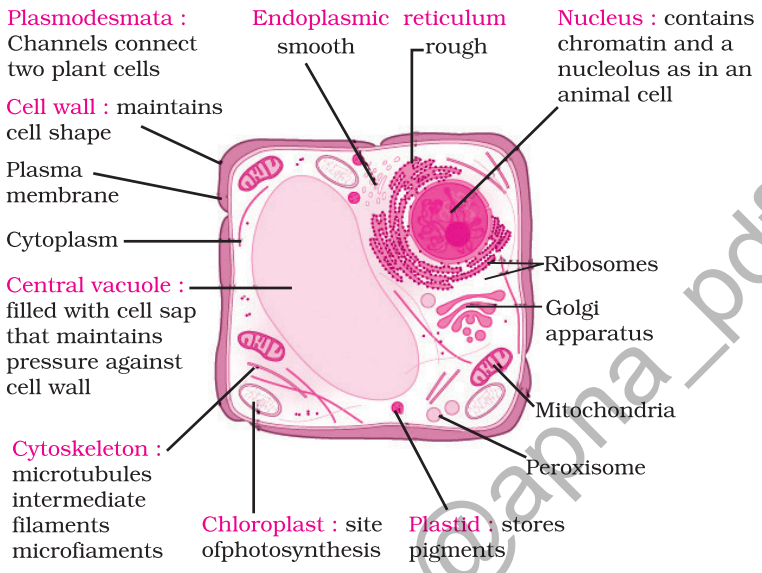
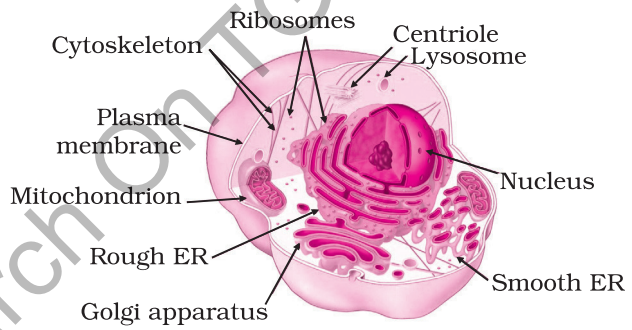
Plant Cell



Animal Cell



➢ **Plasma membrane :** In 1856, Nageli and Cramer reported about the existence of a cell membrane. Later, the famous botanist Plowe (1931) named it as plasmalimma (or "Plasmamembrane"). Its presence in all types of cells is defined as a thin semi-permeable biological membrane of a cell, composed of two layers of phospholipids, which provide it semi-permeability with phosphate head being polar (water loving), fatty acid tails non-polar (water fearing) and the proteins embedded in membrane. These proteins, intrinsic and extrinsic, provide support and flexibility to a cell. It not only separates the contents of the cell from its outside environment but also regulates the entry and exit of the substances across it with mechanism passive transport and active transport.

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Functions of a cell membrane :

(i) It gives the shape to cells.

(ii) It gives origin to membrane bound cytoplasmic organelles.

(iii) It separates the protoplasm from the extracellular fluid.

(iv) In animal tissues, the cell membrane forms linkage or places of close contact between the adjacent cells. This helps to maintain structural and functional integrity of tissues and organs.

(v) It maintains the excitability (*i.e.*, capacity to respond to a stimulus) of the living cells.

(vi) The cell membrane acts as a medium of exchange (or transport) of materials between protoplasm and extracellular fluid.

- **Cell Wall :** Found exclusively in plant cells made up of cellulose and semi-cellulose (structural carbohydrate). Hemicellulose, pectins and proteins.

  Functions of cell wall : It being a non-living structure provides shape, protection and mechanical strength to counteract turgor pressure and prevent the bursting of turgid cells along with help in checking the movement of substances into or out of a cell.

  In fungi, a cell wall is made of chitin and in bacteria of polysaccharides and proteins.

- **Nucleus :** It is centrally placed in an animal cell or at the periphery in a plant cell, it was first explained by Robert Brown in 1831. It is spherical or oval-shaped structure considered as the control centre of the cell. Its contents, the thread-like chromatin material composed of DNA carrying genes and nucleolus in nucleoplasm, are well separated from cell cytoplasm by nuclear envelope having pores to allow the movement of substances including RNAs in eukaryotic cells.

Syncitium : A multinucleated animal cell
Coenocyte : A mutinucleated plant cell.
Karyotheca : The double membrane covering of the nuclues.

  In prokarotic cells, the nuclear DNA bound with histones is found in cytoplasm. However, some prokaryotes also have extra nuclear material called plasmid like *E. coli, Agrobacterium,* etc.

- **Nucleolus :** It is the structure with no membrane acts as the site for active ribosomal RNA synthesis present in nucleus.

- **Chromosomes :** These are long thread-like structures present in the middle of nucleus as network but are clearly visible during metaphase. Each species of plants and animals has a specific number of chromosomes as listed in the given table.

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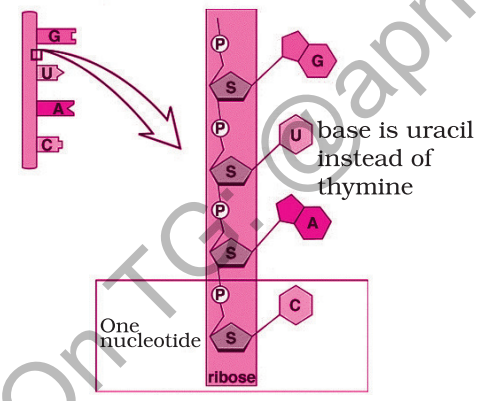
Species	Pair of chromosomes
Human	23 (22+1)
Monkey	21
Housefly	06
Mosquito	03
Dog	39

- **Nucleic acids :** These are of two types : **DNA and RNA.**
- **RNA :** It is found both in nucleus and cytoplasm as a single–stranded structure with ribose sugar and four nitrogenous bases: Adenine, Guanine,Uracil and Cytosine.

Structure of RNA



Types of RNA : There are three main types of RNA:

- **Messenger RNA (mRNA) :** only about 3-5% transcribes genetic information from the DNA found in the nucleus of a cell's and then carries this information to the cytoplasm of the cell and ribosome.
- **Transfer RNA (tRNA) :** is found in the cytoplasm of a cell and is closely related to mRNA as its helper. tRNA (12-15%) literally transfers amino acids, the core components of proteins, to the mRNA in a ribosome.
- **Ribosomal RNA (rRNA) :** is found in the cytoplasm (80%) of a cell. In the ribosome, it takes mRNA and tRNA and translates the information they provide. From this information, it "learns" whether it should create or synthesize, a polypeptide or protein.
- **DNA :** It is found only in nucleus associated with chromatin material or chromosome. It is double stranded with sugar of deoxyribose type and the four bases : Adenine, Guanine, Cytosine and Thymine as proposed by Watson and Crick. The two strands have a backbone of

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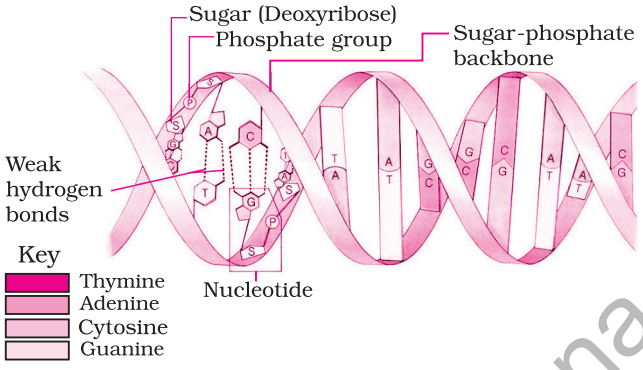
phosphate and sugar bonded together with phosphodiester bonds. In the middle , the nitrogenous bases have either double or triple hydrogen bonds.



Structure of DNA

- **DNA v/s RNA :** DNA contains the sugar deoxyribose, while RNA contains the sugar ribose. The only difference between ribose and deoxyribose is that ribose has one more -OH group than deoxyribose, which has -H attached to the second (2') carbon in the ring.
  - — DNA is a double stranded molecule while RNA is a single stranded molecule.
  - — Both DNA and RNA have purine and pyrimidine bases. It's just that RNA has uracial instead of thymine present in DNA.
  - — DNA is stable under alkaline conditions while RNA is not stable.
  - — DNA and RNA perform different functions in humans. DNA is responsible for storing and transferring genetic information while RNA directly codes for amino acids and acts as a messenger between DNA and ribosomes to make proteins.
- **Mitochondria :** These are double membranous thermos bottle-shaped structures with the inner membrane folded inwardly in finger-like projections called cristae as discovered by Altman and described by Benda.
  - (i) **Functions of Mitochondria :** They carry F-1 particles, the site of ETC(Electron Transport Chain) on the inside lining of cristae. These are the site of cellular respiration (Kreb's cycle and ETC), *i.e.* oxidative phosphorylation that involves the release energy in form of ATP hence, considered as the power house of a cell. DNA along with 705 ribosome are found only in mitochondria other than nucleus.
  - (i) They carry out fatty acid synthesis and production of DNA, RNA and some proteins for enzymes synthesis.
- **Number of mitochondria and a cell :** Mitochondria, (1-2m) are the site of cellular respiration. Their number is more in cells involved in physical work like the cells of a bird's wings or muscle cells in animals.

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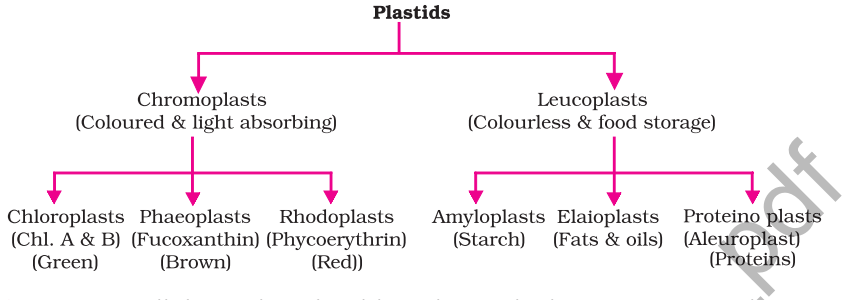
- **Plastids :** These are double membranous structures found only in plant cells. There are different types of plastids involved in photosynthesis or storage of food as listed below :



- Among all these plastids, chloroplasts which impart green colour to plant parts play a crucial role in photosynthesis for the sustenance of life on the earth. All non-green plants, herbivores, carnivores and omnivores depend directly or indirectly on them. Hence, they are rightly considered as the primary producers in an ecosystem.
- **Semi-autonomous cell organelles :** In a cell, mitochondria and chloroplasts are the two semi-autonomous organelles, *i.e.* endo-symbiotic with their own nuclear material and ribosome for protein synthesis. Therefore, a mitochondrion can survive for some time even after its isolation from a cell.
- **Endoplasmic reticulum :** These are membranous folds consisting of cisternae, vesicles and tubules which form cytoskeleton as observed and first described by Porter and Claude in 1945. These are of two types ;
- **SERs** (without ribosome) The main function of SERs is fynthesis of lipids which include steriods necessary for synthesis of hormones. They are considered responsible for detoxification and play an important role in muscular contraction by releasing and trapping calcium ions.
- **RERs** (with ribosome) are involved in protein synthesis. These are mostly found attached to nuclear membrane to remain in close vicinity of nucleus. Cells involved in protein synthesis have plenty of them.
- **Golgi bodies/apparatus :** These are called dictyosome in plant cells and are formed from endoplasmic reticulum as proposed by membrane flow hypothesis. They as described by Camillio Golgi are actively involved in the process of cell excretion and secretion being involved in the formation of lysosome and secretary vesicles for extracellular secretion. It is important site of formation of glycoproteins and glycolipids.

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- **Lysosomes :** These are single membranous structures described by Christan D-Duve. They contain hydrolytic enzymes for the intracellular digestion and digestion of ageing cell organelles. However, during cell starvation, they cause self-cell death by digesting the important active cell organelles, *i.e.* the cellular suicide is known as Apoptosis. Hence, they are also called suicidal bags.

  Lysosomes are not found in RBCs.
- **Giant lysosome :** It refers to the acrosome found at the tip of a spermatozoan. It helps in the hydrolysis of the ovum wall for the entry of the male nucleus inside ovum for fertilization.
- **Peroxisomes :** They are small–sized organelles containing enzymes like catalyses and oxidases. These are the site of photorespiration in plant cells and lipid metabolism in an animal cell.
- **Glyoxysomes :** These are small spherical bodies having high deposits of fats and lipids; enzymes like acid phosphates are also found in them. They are found in the seeds of groundnut and castor (that contain fatty acids). During seed germination, they convert fatty acids to soluble carbohydrates (glycoxylate cycle) to provide energy.
- **Ribosomes :** These are small non-membranous granular structures made up of RNA and as first observed and described by G.E.Palade in 1953. When attached to mRNA strand, they form polyribosomes. They are actively involved in the process of protein synthesis, hence, considered as protein factories of a cell.
- Each ribosome is divided into two subunits, a smaller subunit which binds to a larger subunit and the mRNA strand, and second the larger subunit which binds to the tRNA, the amino acids, and the smaller subunit. When a ribosome finishes reading an mRNA molecule, these two subunits split apart.
- **Centrioles :** They are not surrounded by a membranous covering show 9+2 pattern of the arrangement of microtubules. They are involved in the formation of spindle-fibres at the time of cell division, formation of cilia and flagella of the cell and help in the formation of sperms from spermatids during spermiogenesis.
- **Cilia and flagella :** These are long, cylindrical tubes made up of proteins like tubulin and actin. They are the organs of locomotion in unicellular organisms and help in the transport of substances in higher organisms.
- **Vacuoles :** These are single membranous structures found more prominently in plant cells than in animal cells where they are either absent or if present, are small in size. With a single membrane called tonoplast, they store the water and minerals to maintain cell turgidity. Present as gaso-vacuole in algae, they help them float on the surface of water.

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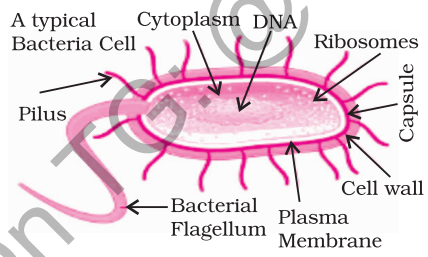
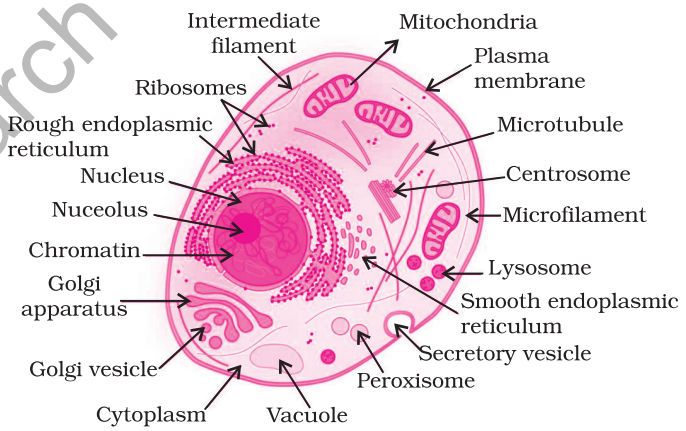
- **Single membranous cell organelles** include lysosomes and vacuoles.
- **Non-membranous cell organelles** include ribosome, nucleolus and centriole.

	Plant cell	Animal cell
1.	Outermost covering is of dead cell wall made of cellulose.	Outermost covering is of living plasma membrane made of proteins and phospholipids.
2.	Plastids of different types are present.	Plastids are absent.
3.	Nucleus is placed peripheraly with large vacuole in centre.	Nucleus is centrally placed with small vacuoles.
4.	Lack centriole, the spindle fibre forming structure.	They possess centriole, the spindle forming structure.



Prokaryotic cell



Eucaryotic cell

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Differences between Prokaryotic cells and Eukaryotic cells	
Prokaryotic Cells	**Eukaryotic Cells**
They are primitive with very minute size of 1-10μm.	They are compartively advanced and larger in size10 - 100μm.
Nuclear region (nucleoid) is not enveloped by a nuclear membrane.	Nucleus is surrounded by a double membrane layer.
Single circular chromosome is present.	More than one linear chromosomes are present.
Nucleolus is absent.	Nucleolus is present.
Membrane-bound organelles are absent.	Membrane-bound organelles are present.
Multiplication of a cell is by fission or budding.	Cell division by mitosis or meiosis.
Cell type is usually unicellular.	Usually multicellular cells.
Have 70S type ribosome	Have 80S type ribosome

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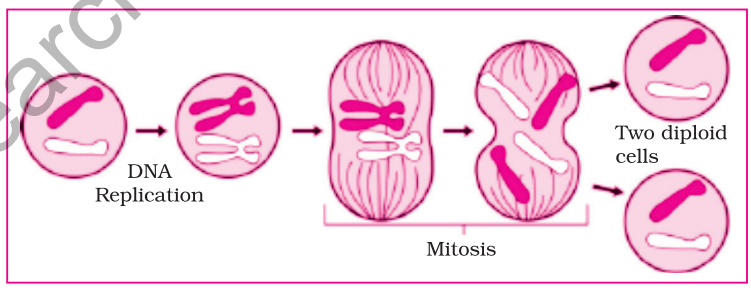
Cell division and its types with stages of cell cycle

- **Cell division :** It was first observed by Flemming in 1882 but later well described by Belar in 1920, it is the mode of the cell reproduction either for the growth of an organism, repair or replacement of damaged body parts or involved in sex cell formation in higher organisms prior to reproduction. Each cell division involves karyokinesis and cytokinesis.
- **Totipotency :** It's the property of a plant cell to maintain its ability to divide when mature.
- **Karyokinesis :** It is the division of nucleus in a cell mostly followed by the division of cell cytoplasm to produce two daughter cells.
- **Cytokinesis :** It is the division of cell cytoplasm to form two daughter cells. However, in some cases such as in unicellular organisms during multiple fission or in multi nucleated cells, karyokinesis may not be followed by cytokinesis.
- **Kinetochore :** It is the protein complex formed on the chromatids during cells division. It allows to attach the spindles fibers to pull the sister chromatids apart.
- **Centromere :** It is the area where both chromatids are in contact with each other. The kinetochores are on the outer sides of the centromere.
- **Polytene or Lampbrush chromosomes :** These are the largest known chromosomes found in the cells of salivary glands. Hence, they are widely used in genetical studies.

- **Discovery of cell division :** W. Flemming discovered mitosis and O.Hertwig discovered meiosis.
- **Anastral mitosis :** It is known to take place in plant cells as they lack centrioles, hence, spindle fibre formation does not occur.
- **Interphase :** A phase in a cell cycle in which DNA undergoes replication but chromosomes still appear intertwined thread-like structures not easily distinguishable. The cell also shows a pair of centrioles, the organization site for microtubules involved in spindle formation. It is the longest of all the phases of a cell cycle, also called resting phase but in reality being the most active phase being involved in DNA replication. It prepares cell for cell division.
- **Prophase :** It's the phase of cell division that involves condensation of chromatin material into chromosomes so that they may become more visible, the disintegration of nucleolus and nuclear envelop and movement of daughter centrioles to be the opposite poles of a cell. It is the longest of all the phases of cell division.
- **Condensation of chromatin material :** During prophase chromatin material condenses 1/25 times of its total length.
- **Metaphase :** It's the shortest of all phases of cell division that involves the arrangement of all chromosomes in the middle of the equatorial plane. This stage is best for the microscopic study of chromosomes and development of karyotype of an organism.
- **Anaphase :** It's a phase that involves the separation of paired chromosomes with each moving towards the opposite poles with condensing astral rays made up of micro-tubules.
- **Telophase :** It's the phase that marks the arrival of chromatids at opposite poles followed by their elongation, regeneration of nucleolus and nuclear membrane. Hence in later phases , it completes with cytokinesis.
- **Telophase in plant cell :** It is achieved by the deposition of cell plates formed of dictyosomes.
- **Meiosis :** It's a reductional division restricted to germinal cells involved in the formation of germ cells, also called gametes. They carry half the number (haploid) chromosomes compared to the number of chromosomes present in the parental cell.



- **Meiosis-I :** It involves the pairing of homologous chromosomes followed by crossing over. In meiosis-I, prophase-I is the most important phase with five sub-phases of leptotene, zygotene, pachytene, diplotene and diakinesis. It is in pachytene that crossing over takes place to produce variations.

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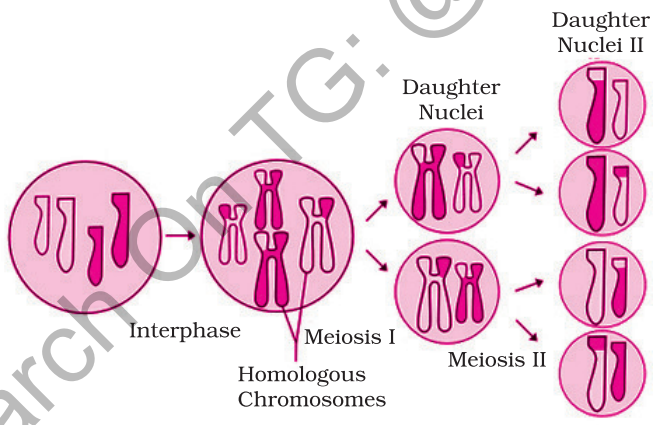
Difference between Mitosis and Meiosis		
	Mitosis	**Meiosis**
1.	Occurs in vegetative/ somatic cells.	Occurs in germinal cells.
2.	Does not involve the pairing of homologous chromosomes and crossing over.	Involves the pairing of homologous chromosomes and crossing over.
3.	Produces two cells with the same number of chromoso-mes. (diploid)	Produces four cells with half the number of chromosomes. (haploid)
4.	Does not contribute to the origin of variation.	Contributes to variations.

Changes in the number of chromosomes and chromatids:

- From the onset of synthetic (S) phase of cell cycle until the completion of cell division , the number of chromosomes and chromatids varies both in mitosis and meiosis such as in human cells as listed in the table given below.



Mitosist	Cell at rest	S-phase	Metaphase	Daughter cell
No. of chromosomes	46	46	46	46
No. of chromatids	46	92	92	46
Meiosis	**Meiosis-I**		**Meiosis-II**	
No. of chromosomes	46	46	23	23
No. of chromatids	46	92	46	23

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Chapter 2

TISSUES STRUCTURE AND FUNCTIONS

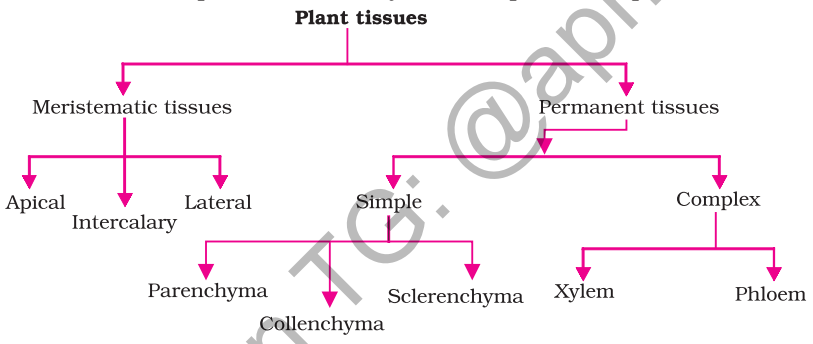
Tissue, types of plant tissues, meristematic tissues, simple permanent tissues i.e. parenchyma, collenchyma, sclerenchyma, composite permanent tissues, i.e. xylem and phloem : their composition and functions.

Animal tissues and their types : epithelial tissues, muscular tissues, connective tissues and nervous tissues, their types with functions.

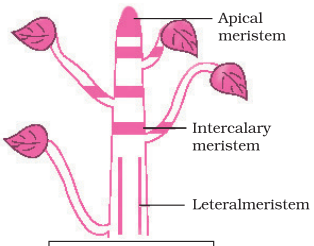
BIOLOGY

PLANT TISSUES

- **Tissue :** It is a group of cells similar in structure and functions. However, a tissue may consist of cells not similar in structure but involved in carrying out a specific function. Therefore, based on the above aspect a tissue may be a simple or complex tissue.



- **Meristematic tissue :** It's small cells with no intercellural spaces are, round multisided thin-walled, have no central vacuole and no specialized features except cells are metabolically active with pronounced nucleus being involved in cell division, plant growth, repair and regeneration of plant parts.
- **Apical meristems :** Meristematic tissue at the growing tip points of roots and stems. It is responsible for the vertical plant growth *i.e.* growth of stem in height and root in depth.
- **Secondary meristems :** These are either intercalary or lateral meristems.
- **Intercalary meristem :** Refers to lateral buds at the nodes of stems from where lateral branching occurs.
- **Lateral meristem :** In some plants, they are called cambium found within mature stems and roots for lateral growth in the girth of stem and root. They are lacking in monocot plants which lack secondary growth.
- **Permanent tissues :** These tissues have permanent shaped cells which perform a specific function. There are different types of them.



Meristematic tissues

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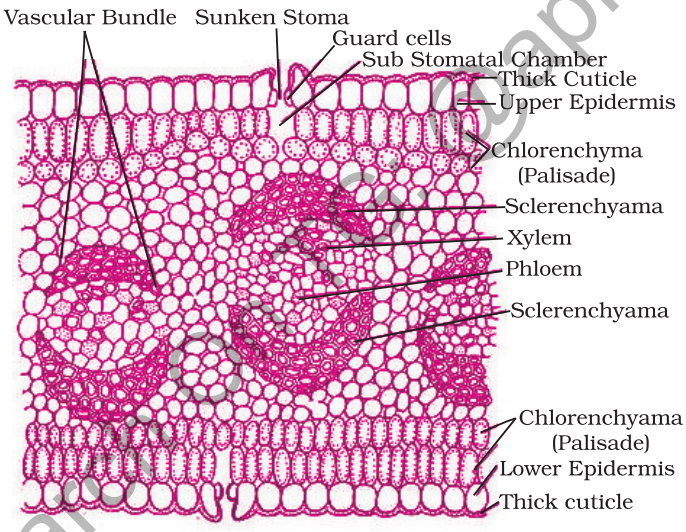
- **Parenchyma :** These tissues are with large, thin-walled cells and a large central vacuole. In areas not exposed to light, their cells have colourless plastids, leucoplasts for food storage. The cells of the white potato are parenchyma cells. Parenchyma cells involved in photosynthesis are called chlorenchyma.
- **Chlorenchyma :** It is a modified form of parenchyma in regions exposed to light,Eg., in leaves, presence of chloroplasts predominates in palisade cells and photosynthesis is the main function.
- **Aerenchyma :** In aquatic plants, leaves and stems, these are parenchyma cells found filled with air to provide necessary buoyancy for floating in water.
- **Collenchyma :** These are tissues like parenchyma but with cells having thick walls, especially at their corners for providing mechanical support particularly in areas that grow rapidly and need to be strengthened such as the petiole, stalk of leaves is usually reinforced with collenchyma. Their presence allow the leaves or branches to bend without breaking.



Anatomy of xerophytic leaf V.S. of leaf of Agave (monocot) showing detailed structure

- **Sclerenchyma :** These are tissues with a very thick uniform layer around the entire margin of the protoplasm in a cell. Often, the cell dies after its cell wall is fully formed. They are usually found associated with other cell types furnishing them mechanical support. These are mostly found in stems, in leaf veins and in making up the hard outer covering of seeds and nuts. The cotton or jute fibres are the types of sclerenchyma tissue. These tissues can be in form of long elongated fibres or irregular shaped sclerids which impart grit to fruits. ex. husk of coconut.
- **Xylem :** Complex permanent tissues responsible for the conduction of water and dissolved minerals from the roots to all the other

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plant parts under the effect of transpiration pull against the force of gravity to the great heights of a tree. They are composed of three dead and one living components.

- **Xylem fibres :** The sclerenchyma fibres associated with xylem tissue are known as xylem fibres.

  They are of two types, *i.e.* fibre tracheids and libriform fibres, but they always remain in intermingled condition.

  The cells are represented by dead elongated fibres with lignified walls.
- **Xylem vessels :** These are thick-walled tubes that can extend vertically through several feet of xylem tissue. Their diameter may be as large as 0.7 mm. Their walls are thickened with secondary deposits of cellulose and are usually further strengthened by impregnation with lignin. The secondary walls of the xylem vessels are deposited in spirals and rings and are usually perforated by pits for the lateral transport of water and minerals.
- **Tracheids :** These are dead with thick, lignified walls and at maturity, lack cytoplasm. Gymnosperms and ferns lack vessel cells but have tracheids with pits for water and mineral transport.
- The other constituents of xylem are living xylem parenchyma.
- **Phloem :** These are complex permanent tissues responsible for the conduction of the synthesized food in green plant parts to non-green plant parts in the form of sucrose sugar. It has two main components, sieve elements and companion cells along with fibres and phloem parenchyma.
- **Sieve elements :** They have perforated end walls to allow cytoplasmic connections between vertically stacked cells. The result is a **sieve tube** that conducts the products of photosynthesis like sugars and amino acids from a source, e.g., leaves, to the sinks *i.e.* places where they are consumed or stored; such as roots, growing tips of stems and leaves, fruits, tubers, corms, etc. Sieve elements have no nucleus, i.e. are non-nucleated living plant cells like RBCs in human blood.
- **Companion cells :** These cells are found adjacent to sieve cells to provide help in any function that is energy-dependent.
- **Phloem parnchyma :** These are parenchymatous tissues present in a angiospermic dicotylednous plant only.
- **Vascular tissues :** Xylem and phloem together being responsible for the transport of water, minerals and synthesized food are called vascular tissues. A mass of xylem together with phloem in stem and root is called vascular bundle. They are also called as 'fascicle.'
- **Open vascular bundle :** It's a conjoint vascular bundle in which a strip of cambium lies between xylem and phloem. It is known as fascicular cambium.
- **Closed vascular bundle :** It's a conjoint vascular bundle which lacks a strip of cambium between xylem and phloem. They donot show secondary growth.
- **Cambium :** It is the meristematic tissue which is responsible for secondary growth in plants.
- **Inter-fasicular cambium :** It's a strip of cambium formed in between two intra-fasicular cambia from the cells of medullary rays.

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- **Intra-fasicular cambium :** It's a strip of cambium present in between primary xylem and phloem of the vascular bundle.
- **Primary xylem or phloem :** These are vascular tissues developed from pro-cambium in embryo.
- **Secondary xylem or phloem :** These are vascular tissues developed from primary xylem or phloem.
- **Medullary rays :** These are the strips of parenchyma present between the vascular bundles of dicot stem.
- **Characteristic features of dicot stem :** Epidermis with cuticle, multicellular hair. Hypodermis of a few layers of collenchyma with ground tissue differentiated into cortex, endodermis, pericycle, medullary rays and pith. Conjoint, collateral, open and endarch, wedge-shaped vascular bundles , arranged in a ring. Bundle Sheath are absent. They are solid.
- **Characteristic features of monocot stem:** Epidermis with cuticle, but without hair. Hypodermis of a few layers of sclerenchymatous cells with undifferentiated ground tissue. Conjoint, collateral , closed and endarch, oval-shaped vascular bundles non-uniformly arranged but found scattered. Bundle sheath present. May be solid or hollow.
- **Characteristic features of dicot root :** It is a tap roots system which bears thin-walled root hair, ground tissue differentiated into cortex , endodermis , pericycle and pith with 2-6 alternate vascular bundles of xylem and phloem. Xylem bundles are exarch and vessels are polygonal.
- **Characteristic features of monocot root :** It fibrous root system which bears thin-walled root hair, ground tissue differentiated into cortex, endodermis, pericycle and pith with 8 or more alternate vascular bundles of xylem and phloem. Xylem bundles are exarch and vessels are oval.
- **Characteristic features of dicot leaf :** These leaves have dorsiventral symmetry. Thick cuticle at upper epidermis while thin at lower epidermis, more number of stomata on lower surface with mesophyll differentiated into palisade and spongy parenchyma. The epidermis lacks bulliform cells for the rolling or unrolling of a leaf.
- **Characteristic features of monocot leaf :** These leaves have isobilateral symmetry. Uniformly thick cuticle both at upper epidermis and lower epidermis, equal number of stomata on both surfaces with mesophyll not differentiated into palisade and spongy parenchyma. The epidermis possesses bulliform cells for the rolling or unrolling of a leaf.
- **Secondary growth :** Characteristic of dicot plants because of which stem grows in thickness with increasing girth. It's because of lateral meristem called cambium/vascular cambium. It with the passage of time adds a number of xylem and phloem elements which contribute to an increase in thickness.
- **Annual rings :** The alternate layers of soft and hard *i.e.* spring and autumn wood represents difference in growth pattern and wood type produced hence called annual rings. The number of these annual rings helps to estimate the life of a tree.

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- **Spring wood :** In dicot plants, spring season favours growth; the cells formed are thin-walled and light making up soft wood.
- **Autumn wood :** In dicot plants, autumn season is not favourable for growth. Hence, darkly stained thick-walled cells of autumn wood are produced.
- **Cork cambium :** In dicot plant stems, the continuous secondary growth develops and transforms some of cells as meristematic cells forming cork cambium. The cells of cork cambium divide both outwardly and inwardly. The cells formed outside soon get suberised and die forming cork.
- **Cork :** It is impermeable, insulating layer consisting of suberised cells formed by an activity of cork cambium that is removed from time to time for commercial purposes particularly from a cork tree, *Queracus super*. It is usually formed during secondary growth through activity of the phellogen.
- **Phelloderm :** In dicot plants the cells formed inside by an activity of cork cambium are parenchymatous or collenchymatous. They form secondary cortex, phelloderm.
- **Periderm :** The cork, cork cambium and secondary cortex constitute periderm.

Animal Tissues

- **Animal tissues :** The tissues which make up the body of higher animals are called animal tissues.

Tissue type	Functions
Epithelial tissue	Covers body surface, lines body cavities, providing secretions.
Connective tissue	Binds and provide support to body parts.
Muscular tissue	Enables the movement of structures within the body and of the body as a whole.
Nervous tissue	Enables responses to stimuli and coordinate bodily protection and functions.

- **Epithelial Tissue :** "The covering or protective tissues in the body are called epithelial tissues". These tissues exist in many forms and can be classified or sub-divided in different ways.
- **Classification based on shape :** Squamous , cubodial , columnar and transitional epithelial tissues.

Classification by Arrangement of Layers :

Simple/Stratified squamous epithelium,	Simple / stratified cuboidal epithelium,
Non-ciliated simple/stratified columnar epithelium,	Ciliated simple / stratified columnar epithelium.

- **Glandular Epithelial Tissue :** Epithelial tissue found in endocrine (hormone secreting) and exocrine (enzymes secreting) glands.

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- **Connective Tissue :** These tissues serve the general purpose of supporting and connecting the tissues of the body, and vary considerably in structure and composition. They are of different types.
- **Loose connective tissues :** These tissues are also called connective tissues. These include areolar tissues , adipose tissues and reticular tissues.
- **Areolar tissues :** These tissues consist of a mesh of collagen, elastic tissue and reticular fibres - with many connective tissue cells in between the meshwork of fibres. These cells include fibroblasts which are involved in the synthesis of fibres, mast cells responsible for allergic action and macrophages, the W.B.C.s meant for the phagocytosis of antigens.
- **Dense connective tissue :** These include white fibrous tissue and yellow elastic tissue.
- **Ligaments :** They connect bone to bone and help to stabilize joints they surround. They are mostly composed of long, stringy collagen fibres which create the bands of tough, fibrous connective tissues. They are slightly elastic, so that they may be stretched and gradually lengthened, increasing flexibility.
- **Tendon :** They connect muscle to bone. These are tough yet flexible bands of fibrous tissues made of elastin fibers which hold the skeletal muscles attached to the bones they move.
- **Adipose tissue :** It being made of subcutaneous fats is found underneath the skin and around the important body organs. It is meant to provide protection from external shocks and insulation to the body parts.
- **Cartilage :** It is a type of connective tissue composed of special cells called chondriocytes along with collagen or yellow elastic fibres. They smoothens the bone surfaces at the joints. The fibres and cells are embedded in a firm gel-like matrix rich in muco-polysaccharides. It is not so hard and rigid as bone but much more flexible and elastic.
- **Hyaline cartilage :** This type of cartilage, bluish-white in colour and flexible has very thin fibres which is hardly visible. It is the articular cartilage of long bones, sternum, ribs, etc.
- **Fibrous cartilage :** It is the strongest type of cartilage having dense collagen fibres. It doesnot have pesichondrium. This type of cartilage, glistening white in colour but opaque in appearance, has numerous white fibres. It is present in the symphysis pubis, and sterno-clavicular joint, etc.
- **Elastic cartilage :** This type of cartilage, yellowish in colour , opaque in appearance, has numerous yellow elastic fibres. It is present in the ear pinna, eustachian tubes, epiglottis, etc. It has a pesichondrium.
- **Bone :** Bones develop from osteoblasts(bone cells) which together make up Haversian canals. They secrete material inside the shaft of the cartilage model of long bones. Later, calcium is deposited, cavities merge to form the marrow cavity and eventually osteoblasts become trapped within their own secretions and become osteocytes (mature bone cells). In a body, bones are meant to provide protection to the shape of a body, help in movement and giving a body a specific shape. In the bone marrow of long bones which has a protective surface membrane of peritoneum, haemophoesis the development of blood cells, *i.e.* R.B.Cs and W.B.Cs takes place.

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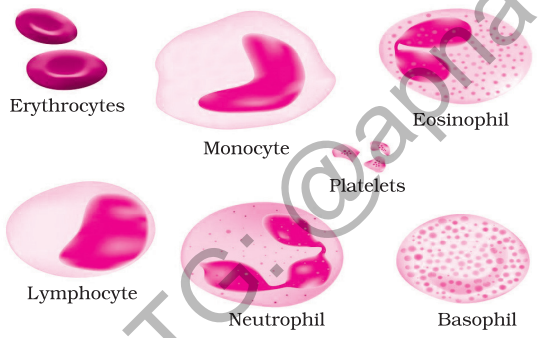
- There are 206 bones in an adult person. In a newly born child, they are 270 or more upto 300 but with age, soem of thesse bones fuse within the first few months by process called ossification.
- **Investing and cartilage bones :** The bones formed by the ossification of cartilages in an embryo such as vertebrae and limb bones are called cartilage bones. The bones formed after the ossification of membranous tissue present below the skin are called investing bones such as the flat bones of skull and face.
- **Vascular tissue :** It includes the tissue present in the form of fluid. It includes blood and lymph.
- **Blood :** It is fluid connective tissue consisting of blood plasma with plasma proteins and the formed elements called blood cells. There are three types of these blood cells: red blood cells, white blood cells and blood platelets also called erythrocytes, leucocytes and thrombocytes respectively.



Elements of Blood

Blood facts	
Blood accounts for 7% of body weight	
Volume :	about 5 litres.
Average density :	1060 kg/m^3
pH :	704
Hb :	Male 13.5-17 gm/dL
	Female 12-15.5 gm/dL
RBC :	5-5.5 million/mm^{-3}
WBC :	6000-8000/mm^{-3}
Platelets (Thrombocytes) :	15,00,00-3,500,00/mm^{-3}

- **Red blood cells :** These are bioconcave shaped living non-nucleated cells with short life-span of 120 days after which they get denatured and die in liver and spleen, the graveyard of RBC's. These cells carry haemoglobin, an iron pigment necessary for oxygen transport from alveoli in lungs to body cells.
- **White blood cells :** These are nucleated blood cells. However, the ratio of RBCs to WBCs is 1000:1. They are basically of two types, phagocytes and lymphocytes.

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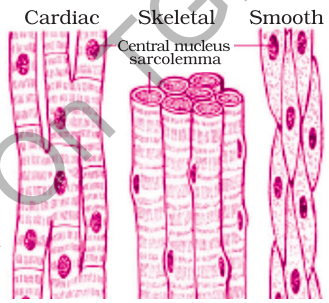
- **Phagocytes :** These WBCs are with a lobed nucleus and have no specific shape as their shape changes during the course of the engulfing (phagocytosis) of antigens.
- **Lymphocytes :** These are oval-shaped cells with ovoid nucleus. They provide protection to a body by producing the necessary antibodies.
- **B- lymphocytes :** The lymphocytes which are formed in bone marrow and mature there only before their release are called B-lymphocytes.
- **T-lymphocytes :** The lymphocytes which are formed in bone marrow but mature in the thymus gland are called T-lymphocytes.
- **Thrombocytes :** These also called blood platelets which are responsible for blood coagulation starting from the plasma protein fibrinogen after an injury to prevent any excess blood loss and direct entry of a pathogen in the body.
- **Thrombocytopenia :** The condition of decrease of platelets in the blood.
- **Lymph :** The white yellow body fluid that is found flowing in lymph nodes and vessels is called lymph. It is like blood in its composition except that it lacks RBCs and thrombocytes, hence, does not play any role in oxygen transport and blood coagulation. It is meant to provide protection to the body against any invasion of antigens by phagocytosis Hence, it is normally found accumulated as pus at the point of infection.
- **Muscular tissues :** These tissues are of three types, based on the differences in their structure, function and location. These are :



- **Skeletal muscles :** Mostly present throughout the body are cylindrical shaped multinucleated with alternate light and dark bands of proteins **actin and myosin**. They are under conscious control, *i.e.* are voluntary. Their main function is to provide movement to body parts or the body as a whole, e.g. walking, running, etc.
- **Cardiac muscles :** These are like skeletal muscles but branched, uninucleated and are not under conscious control, *i.e.* are involuntary. Hence, they also called involuntary striated muscles. They are found only in the middle layer of the heart, the myocardium.
- **Smooth muscular tissues :** These tissues unlike skeletal tissues are uninucleated with the shape of a spindle. These involuntary muscles are found located around the walls of many internal structures such as the stomach and intestines and important for aiding in the passage of materials or fluids through these structures.

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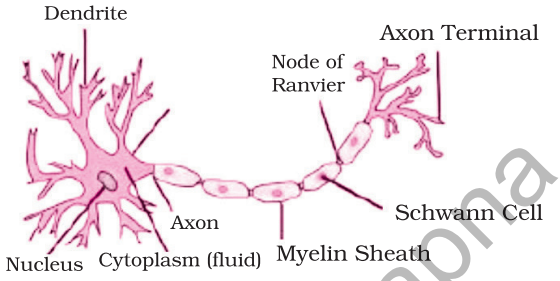
- **Nervous Tissue :** A neuron is the structural and functional unit of the nervous system including of the central nervous system that is comprised of the brain and the spinal cord, the peripheral nervous system of spinal and cranial nerves and autonomous nervous system of sympathetic and parasympathetic nerves.
- **Neuroglia :** These cells are surrounded by the neuron which act as the 'helper cells' that protect, feed and Insulate the neuron. These are mostly found in lower animals.

A Neuron cell



- The different neurons have been given different names as listed below :
- In humans, there are 31 pairs of spinal nerves and 12 pairs of cranial nerves. The spinal nerves interconnect the body-parts to the spinal cord while cranial nerves do it with brain.
- **Sensory and motor nerves :** The nerves which carry the impulses of stimulus to the central nervous systerm *i.e.* brain or spinal cord are called sensory serves while the nerves which carry the impulses of response from the central nervous system to the effector are called motor nerves. These nerves differ structurally too as sensory neuron has laterally placed cyton while motor neuron has only terminal cyton. A neuron without axon is called central neuron.
- **Myelinated neurons v/s non-myelinated neurons:** The neurons with myelin sheath around the axon with node of Ranvier in between are myelinated neurons while those without it are called non-myelinated neurons.
- In myelinated neurons, the conduction of impulse is faster being saltatory conduction compared to non-myelinated neurons.
- **Synapsis :** It is the junction between the two nerves where the message is delivered using chemicals such as acetylcholine or serotonin. These chemicals are known as neurotransmitters. A similar type of junction, called neuro-muscular junction, exists between nerve endings and a muscle that is to be contracted or relaxed. In nerves, the transmission of impulse occurs because of the Na^+ -K^+ pump that involves their unidirectional movement in or across the length of a neuron cell from dendrite to axon than to other dendrites of neuron at synapsis or an effector in a body such as the central nervous system, muscles or glands.

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Chapter 3

Classification Of Plants and Animals

Taxonomy, binomial nomenclature, historical development in the trends of classifying organisms, presently accepted hierarchy of classification. Plant classification including cryptogams and phanerogams.
Animal classification including non-chordate, hemichordate and chordates with the classes of chordates i.e. Pisces, Amphibia, Reptilia, Aves and Mammals.

- Biological diversity refers to the occurrence of the varied forms of life differing in size, appearance, colour, internal structure, mode of living, etc. At present, a number of living organism species known are more than 1.5 million, *i.e.* 1.7 to 1.8 million (IUCN). This diversity has developed because of organic evolution and adaptation of organisms to the diversity of conditions in existence on the earth, *i.e.* hydrosphere, lithosphere and atmosphere.
- Greek philosophers like Aristotle, and his student Theophrastus proposed two kingdom systems having only plants and animals.
- In 1869, three kingdom systems of Plantae, Animalia and Protista were proposed by Ernst Haeckel.
- In 1956, four kingdom systems were proposed by Copeland in 1956.
- In 1968, Robert whittaker devised the system of five kingdoms.
- **Taxonomy :** It is the branch of biological sciences that deals with the identification, nomenclature and classification of an organism.
- **Systematics :** It is the scientific study of biological diversity and its evolutionary history. The systematics and taxonomy are together referred to as systematic biology.
- **Nomenclature :** It is the formal act of naming a particular organism according to an internationally standardized system of binomial nomenclature followed by ICBN (International Code of Botanical Nomenclature) and IUZN (International Code of Zoological Nomenclature). It was first proposed by Carlous Linneaus, also called Father of taxonomy, in his treatise 'Systema Naturae' (1758) and "Species Plantrnum"(1753). According to the system, the first name is the genus name(generic name) and second is species epithet, e.g., *Mangifera indica* is the scientific name of a mango; *Mangifera* represents the genus and *indica* is the species epithet. The basic idea was to maintain the uniformity of names across the world and make them more informative.

Common Name	Scientific Name	Common Name	Scientific Name
Human	*Homo sapiens*	Potato	*Solanum tuberosum*
Dog	*Canis familaris*	Sugar cane	*Sacchrum officinarum*
Cat	*Felix domestica*	Pea	*Pisum sativum*

BIOLOGY

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Housefly	*Musca domesticus*	Rice	*Oryzae sativa*
Frog	*Rana tigrina*	Wheat	*Triticum aestivum*
Cockroach	*Periplenta americana*	Onion	*Allium cepa*
Earthworm	*Pheretima posthuma*	Maize	*Zea mays*

- **Classification :** It is the arrangement of taxa in an order with the purpose of cataloguing and expressing relationships between taxa. Every organism can be classified at seven taxonomic ranks.
- **Taxonomic categories/ranks :** In total there are seven taxonomic categories.
- **Taxon :** It refers to a category in a system of classification.The different taxa include :

Species → Genus → Family → Order → Class → Division (Plants)/ Phylum (Animals) → Kingdom

- In taxon with the increasing level of hierarchy, the number of common characteristics decreases.
- The members of a species have maximum number of similarities among them.
- A species is the only existing taxon; the rest are all the hypothetical taxa. called Kingdom, Phylum(Division in plants), Class , Order, Family and Genus. Kingdom being the highest taxon has the least number of similarities while the species being the only existent taxon has the maximum number of common characteristics among individual members.
- **Species :** A species is a population of plants or animals which are genetically distinct, reproductively isolated and similar in morphological characteristics. The members of a species can freely interbreed among one another. For example, a population of lions represents the species *Panthera leo* and a population of tigers comprises the species *Panthera tigris*.
- **Sibling species :** When two species are morphologically very similar to each other so much so that it may be difficult to distinguish them but nevertheless they are reproductively isolated, *i.e.* cannot interbreed are termed as sibling species a illustrated by genus Drosophila. *Drosophila pseudoobscura* and *D. persimilis* are the two sibling species.
- **Genus :** It is a taxon category consisting of two or more related species. In general, species in a genus usually have many features in common. Such groups of common features are known as correlated characters. Each species of a genus is given a scientific name based on binomial nomenclature. For example : the genus *Solanum* includes the species *Solanum melongena* (brinjal), Solanum tuberosum (potato), *Solanum nirgum* (makoi) and *Solanum xanthocarpum* (Kanteli).
- **Family :** It comprises one or more genera having some common features but differing from the genera of other families in having certain characteristic differences. For instance, the family Graminae contains all the genera of cereals and millets.

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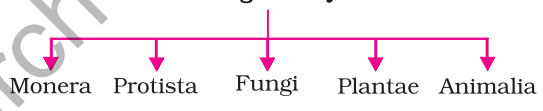
- **Order :** It consists of one or more families having certain common characters which differ from the families of other orders in some diagnostic characteristics. For example, the order Carnivora includes the families Felidae which includes lions, leopards etc and Canidae that includes wild dogs, dogs and foxes.
- **Class :** It consists of one or more orders having certain characters in common but differ from the orders of other classes in some other characters such as the phylum Athropoda among invertebrates have four different classes including Class-Insecta.(The largest class of Animal kingdom) or Bryophytes include liverworts and mosses as two distinct classes.
- **Phylum :** It comprises of one or more classes having certain common diagnostic characters but differs from the classes of other phyla in some other diagnostic characters. In plant classification instead of phylum, word division is used which has its own classes.
- **Kingdom :** It is the highest category in the plan of classification. Each kingdom has several independent phyla which, in turn, represent specific classes, orders, families and genera.
- **Phylogeny :** The evolutionary history of a taxonomic group of organisms is referred to as phylogeny. The classification of organisms based on phylogeny is called phylogenetic evolution as proposed by Adolf Engler and his associate Karl Prantl compared to Natural System of Classification.
- **Natural system of Classification:** This system of classification is based on relationships realizing all information available at the time of the collection of plants. It was proposed by George Bentham and Joseph Dalton Hooker in the mid of the 18th century.
- **Clade :** It is defined as a group consisting of a single common ancestor and all its descendents.
- **R. Whittker** (1969), using the criteria such as complexity of cell structure, body structure and mode of nutrition, proposed five kingdom system. He separated out kingdom Fungi from Plantae.

Five Kingdom System



- **R.Whittker** system has its own shortcomings in the form of no specific place for viruses and placing together of separate heterogeneous groups together such as Slime moulds in Kingdom Protista.

1. **Monera :** It includes all prokaryotes *i.e.* mycoplasma, bacteria and cyanobacteria.

- **Mycoplasma :** They are like bacteria except that they lack cell wall and all are parasitic.
- **Bacteria :** They consist of a wide diversity in shape, size and mode of nutrition from chemosynthetic, saprophytic to parasitic in mode of nutrition and are considered to be omnipresent in all forms of habitats.

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- **Cyanobacteria :** They are also called blue green algae which include organisms like Nostoc, Anabena and Oscillatoria, capable of fixing atmospheric nitrogen into simple nitrogen compounds living freely in soil. For nitrogen fixation, they have specialized cells called heterocyst in their structure.

2. **Protista :** These are unicellular eukaryotic organisms *i.e.* single-celled organisms; they yet show a great diversity in body form, mode of nutrition and reproduction. However, all protists have been further subclassified into three types:
   (i) **Protozoan protists :** These include all forms of protozoa from amoeba, paramecium or paramoecium to plasmodium (causative agent of malaria) and trypanosoma (causative agent of sleeping sickness) among humans.
   (ii) **Photosynthetic protists :** They constitute the majority of phytoplankton such as unicellular green algae. They account for about 70-80% of global photosynthesis. These include:
   (iii) **Dinoflagellates :** These are unicellular flagellated protists. However, many of them occur as symbionts in other organisms like sponges, jellyfish, sea anemones, etc.

- **Diatoms :** They are photosynthetic autotrophs. These are chief oceanic producers, found in both fresh and marine water. They normally reproduce by fission and store food in the form of water-soluble polysaccharide, chrysolaminarin.
- **Euglenoids :** These are freshwater flagellated protists which show the mixotrophic mode of nutrition being photosynthetic during day and heterotrophic at night in the dark such as Euglena.

Amoeba and Paramecium- Free living, *Plasmodium* (Malaria parasite), *Trpanosoma* (African sleeping sickness), *Entamoeba* (Amoebiasis), *Leishmania* (Kala-azar) and *Giardia* (Girdiasis).

- **Slime moulds :** These include heterotrophic protists showing the combined characteristics of protozoa and fungi. They exhibit amoeboid movement like protozoan movement and similarity with fungi in the production of spores.

3. **Fungi :** These include all heterotrophic, spore-forming eukaryotes, unicellular or multicellular. The multicellular organisms are composed of a network of long filamentous, branched structures called hyphae. These hyphae often aggregate to form mycelium. The hyphae in mycelium may be septate or not; if not, they are called coenoytic hyphae. All fungi have further been classified based on their types of spores and sexual reproductive structures into four types :

- **Chytridiomycetes :** These fungi reproduce by zoospores that are capable of moving on their own through a liquid medium using single flagella. These are the most primitive fungi.
- **Zygomycetes :** These include fungi which reproduce sexually with meiospores called zygospores and asexually with spongiospores. Black bread mould (*Rhizopus stolonifer)* is the common species of usual occurrence most of these are saprophytes.

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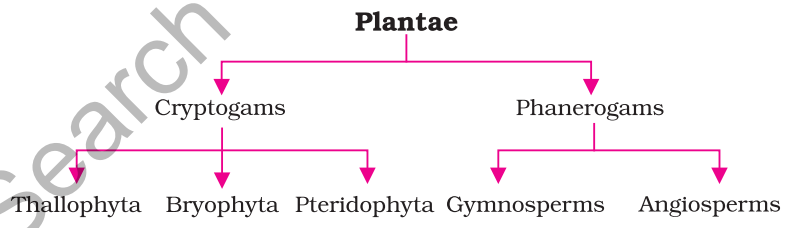
- **Ascomycetes :** These fungi form meiotic spores called ascospores within a special sac-like structure called ascus. They include single-celled yeasts and multicellular mushrooms and truffles.
- **Basidiomycetes :** These fungi produce meispores called basidiospores. They include some species of mushrooms , rust and smut fungi. They have club shaped fruiting bodies called basidia, which act as reproductive organ.
- **Deutromycetes :** These fungi, also called imperfect fungi, lack any sexual phase. They are mostly parasitic such as causative agent of ringworm or athlete's foot in humans.
- **Mycorrhiza :** The mutualistic association between fungi and roots of higher plants such as pine, oak, etc is called mycorrhiza. They absorb water and essential nutrients from soil and provide them to the plant and in exchange the plant provides them with organic nutrients. Sometimes they happen to penetrate into the cortical cells of the plant root as branched structures. Then they are called **arbuscular mycorrihizas** (AM) and if they remain in the form of vesicles, they are called vesicular-arbuscular mycorrhizas (VAMs).
- **Lichens :** These are mutualistic association between algae and fungi. Algae are present in the form of cyanobacteria or multicellular green algae contributing to only five per cent of the total structure while the fungal partner that contributes to the rest of the 95% includes the members of ascomycetes or basdiomycetes. These lichens mostly form the pioneer community of the xeric form of ecological succession as their roots excrete the acids like usanic acid for eroding the rock surface. Some of these also the source of litmus. They are also known to be the natural indicator of air pollution particularly caused by sulphur dioxide whose presence in air enforces them to perish.

4. **Plantae :** This kingdom includes multicellular photosynthetic eukaryotes. Cells have cellulose walls, vacuoles and different photosynthetic pigments. The kingdom has further been classified as :



- **Cryptogamae :** These plants do not bear flowers or seeds and reproduce by spores. They have three divisions: thallophyta, bryophyte and pteridophyta.
- **Thallophyta :** They are most primitive plants devoid of any body differentiation. They are divided into three classes: algae, fungi and lichens.
- **Algae :** These are chlorophyll-bearing thallopytes. These plants based on photosynthetic pigments, storage product, cell wall composition have further been classified into three types:

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	Chlorophyceae	Rhodophyceae	Phaeophyceae
1.	Green algae	Red algae	Brown algae
2.	Cellulose as major cell wall component	Cellulose as major cell wall component	Cellulose along with alginic acid as major cell wall component
3.	Chlorophylls a and b, carotenoids	Chlorophylls a and b, carotenoids, phycobilins the phycoerythrin	Chlorophylls a and c, carotenoids, Xanthophylls such as fucoxanthin are the main pigments
4.	Stored food - Starch	Stored food – Floridean Starch	Stored food – Laminarin and mannitol
5.	Volvox, Ulothrix, Spirogyra	Polysiphonia, Porphyra and Gelidium (rich source of iodine)	Fucus, Sargassum, Laminaria

- **Cryophytes :** These among algae are plants which grow on snow like *Chlamydomonas nivalis* that forms red snow.
- **Fucus and Laminaria :** These algae are rich sources of iodine.
- **Sargasso sea :** It's part of North Atlantic sea because of the abundance of Sargassum species , a marine brown algae.
- **Agar-agar :** A substance used as nutrient medium for culturing micro-organisms is obtained from red algae Gelidium, Gigartina and Gracilaria.
- **Bryophytes :** These plants growing in moist shady places are also called amphibians of plant kingdom as they require water for fertilization, the sperms being motile. In these plants gametophyte dominates the life cycle, the sporophyte being dependent on gametophyte for nutrition. They produce jacketed multicellular sex organs, antheridium (male) and archegonium (female). They are characterized by alternation of generation in their life cycle, i.e. gametophytic and sporophytic phases alternate completely in them. These include dorosoventrally flat bryophytes, called liverworts, such as Riccia and Marchantia and true bryophytes like Funaria.
- **Pteridophytes :** These are sporophytic seedless vascular plants as the sporophyte dominates the life cycle. The diploid sporophyte produces haploid spores by meiosis. Each spore germinates and grows into a gametophyte that produces gametes by mitosis before fertilization. The egg cell is produced in archegonium and motile sperms in antheridium.
- Pteridophytes can be homosporous when all the spores are similar or heterosporous like higher plants. In ferns, the sporangia are found on the undersurface of leaves. The pteridophytes include plants like fern such as Dryopteris (an indoor fern), Adiantum (walking fern), aquatic pteridophytes like Saleginella and Azolla (grown in rice fields for nitrogen fixation) and *Salvania molesta* called sorrow of Kashmir.
- **Gymnosperms :** These are naked seed-bearing plants as ovule is found neither covered before nor after fertilization with ovary. Therefore, they are also called fruitless plants. They possess the

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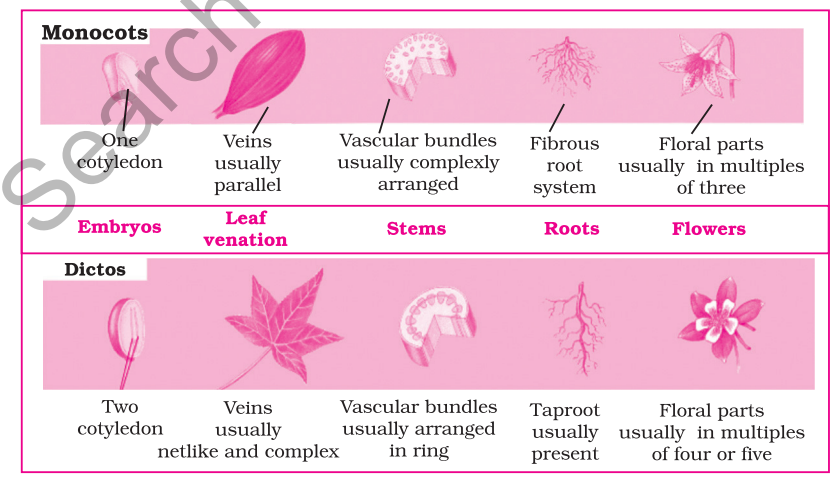
reproductive structures on the undersurface of leaves called sporophylls which may aggregate together to form cones such as found in Pinus. They also do not exhibit the presence of vessel cells in xylem, characteristic double fertilization of sexual reproduction as occurs in angiosperms.

- **Angiosperms :** These include the most developed of plants characterized by double fertilization as mode of sexual reproduction. They bear seeds well enclosed in ovary, the future fruit. However on the basis of the complexity of their structures, they have been classified as monocotyledons and dicotyledonous. Monocotyledons bear fibrous roots and parallel venation in leaves.
- **Phanerogamae :** These are higher plants bearing flowers and seeds. their bodies are differentiated into root, stem and leaves and vascular system; They are well–developed. These are divided into Gymnosperms and Angiosperms:
- **Gymnosperms :** These lack vessel and are the naked seed-bearing vascular plants. They include cycads and conifers:
- **Cycads :** They grow in the warmer regions of the plains and have high ornamental values, e.g., *Cycas circinalis*. Cycads are considered living fossils as they bear flagellated sperms despite the presence of pollen tubes.
- **Conifers :** They are the most predominant gymnosperms, a good source of timber, resin and turpentine oil, *e.g.*, Pine, Fir, Cedar. **Ephedra** is considered as the interlink between gymnosperms and angiosperms.
- **Chilgoza :** It is eaten as a nut in winter and is obtained from the gymnosperm, *Pinus geradiana.*
- **Angiosperms :** These are vascular flowers and seed-bearing plants characterised by their flowers containing the male and female reproductive structures. These are further divided into two groups of monocot and dicot.



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- **Monocotyledons :** They are characterised by parallel venation, equally green leaves on both upper and lower surface, fibrous roots and a single cotyledon in the seed, e.g., wheat (*Triticum vulgare*), rice (*Oryza Sativa*), maize (*Zea mays*).
- **Dicotyledons :** They are characterised by reticulate venation, with upper surface dark green than lower surface, tap root and having two cotyledons in the seed e.g. rose (*Rosa indica*), apple (*Malus silvestris),* pea (*Pisum sativum*).

Comparative features of different land plants

	Bryophyta	Pteridophyta	Gymnosperms	Angiosperms
Dominant phase	Gametophyte	Sporophyte	Sporophyte	Sporophyte
Vascular system	Absent	Present	Present	Present
Sex organs	Present	Present	Present	Absent
Male sex organ	Present	Present	Absent	Absent
Female sex organ	Present	Present	Present	Absent
Male gamete	Motile	Motile	—	—

Plants and families

- **Floral diagram :** It represents a cross-section of a flower as it would appear if all parts were at the same level. Unlike the floral formula, a floral diagram is actually a good representation of the picture of the flower.
- **Floral formula :** It is a "shorthand" used for representing the structure of a flower using the standard set of symbols as listed in the table below :

Br	Bracteate	K	Calyx
C	Corolla	P	Perianth
A	Androecium	G	Gynoecium
$\underline{G}$	Superior ovary	$\overline{G}$	Inferior ovary
♂	Male	♀	Female
⚥	Bisexual	⊕	Actinomorphic
%	Zygomorphic		

- The symbols above represent "attached" floral parts. If the attachment is at a place other than the hypanthium, a line is drawn to indicate the structure to which it is attached.

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- **Example of floral formula :** Number of Parts K 5 = calyx of 5 sepals, C 6 = corolla of 6 petals, A10 = androecium of 10 stamens G2 = gynoecium of 2 carpels C 0 = corolla missing , A4[5] = androecium usually of 4 stamens, rarely 5. For example K5 C(1) +(2)+2 A9 +1 G1.

Important Families and their floral diagrams		
Name of Plant	**Floral formula**	**Family**
Rose	⊕" K(5) C5 ∞" G(1–5)	Rosaceae-Apple, Peach, Strawberry
Mustard	F.F. ⊕ ⚥ $K_2+_2C_{x4}A_{2+4}G_{(2)}$	Brassica/Cuciferae-Radish, Turnip, Cauli-flower
Wheat	Br.Brl. +. ⊕ ⚥ $P_{2\text{-}3\ lodicules}A_{3\text{-}6}\ G_1$	Gramineae-oat Rice, maize,barley
Onion	F.F. . +. ⊕ ⚥ $P_{3+3}\ A_{3+3}\ G_{(3)}$	Liliaceae-Aloe, Yucca, Smilax, Garlic
Gram	F.F. Br .+ ⊕ ⚥ $K_{(3)}\ C_{1+2+(2)}\ A_{1+9}\ G_1$	Papilionaceae- Green gram, Pea, Soyabean
Sunflower	F.F. ⊕ ⚥ $K_{2scales}\ C_5\ \hat{A}_5\ G_{(2)}$	Compositae - Lettuce, Safflower,
Petunia	⊕ ⚥ $K_{(5)}C_{(5)}\ \hat{A}_5\ G_{(2)}$	Solanaceae-Potato, Brinjal, Tomato.

5. Animal Classification

- **Levels of organization :** Although animals are multicellular yet do not exhibit the same level of organization. The organization can be at cellular level, tissue level or organ level depending upon the complexity of their body structures.
- **Body plan in animals :** Body plan refers to a set of morphological and developmental characters that are integrated into a single functional unit.There are three types of body plans in animal kingdom, *i.e.*
- **Cell aggregate plan :** It is the simplest of the plans found in animals with bodies made up of a cluster of cells such as in sponges.
- **Blind sac plan :** A slightly more complex body plans as exhibited by coelenterates like hydra and flatworms except tapeworm. The plan includes a single digestive cavity with one opening both for **ingestion and egestion**.
- **Tube within a tube plan :** The most complex of plans exhibited by higher animals from earthworms to humans. However, it can be of two types:

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- **Protostomic :** When the mouth of the digestive tract develops first such as in insects, molluscs, etc.
- **Deutrostomic :** When anus happens to develop first such as in echinoderms and all chordates.
- **Body symmetry :** It refers to the similarities of body parts, indifferent regions and direction of the body. An animal's body can be asymmetrical, radial or bilaterally symmetrical. Animals such as amoeba , sponges or mature snails are asymmetrical with body that cannot be divided into two equal halves.
- **Radial symmetry v/s bilateral symmetry :** In radially symmetrical animals, a body can be divided into two equivalent halves by any longitudinal plane that passes through the central axis such as in jellyfish , corals, sea anemones , etc. The symmetry is called bilateral when the body can be divided into two equal halves by only one plane such as in all chordates.
- **Coelom :** It is defined as a body cavity lined with mesoderm separating the vital body organs from the body wall. In diploblastic animals which lack mesoderm , the presence of true coelom is not possible. Hence, on the basis of its presence or absence, animals can be coelomate like all chordates or acoelomate like the members of phylum porifera, coelentrata and platyhelminthes. However, the members of the phylum aschelminthes, *i.e.* round worms are considered pseudocoelomate. In these animals , the coelom develops from embryonic blastocoel without mesoderm. In this the body cavity is not completely lined by the tissues.
- **Types of nutrition in animals :** All animals based on their nutrition have been classified as :
- **Herbivores :** These are plant-eating animals such as cow, deer, etc.
- **Carnivores :** These are flesh-eating animals such as lions, tigers, etc.
- **Omnivores :** These are both plant-and flesh-eating animals depending on the availability of food such as humans, bears, dogs, etc.
- **Respiratory system in animals :** Animals vary vividly in their mode of respiration, *i.e.* gaseous exchange depending upon their habitat. Lower aquatic or semi-aquatic animals carry out gaseous exchange through their skin surfaces while higher aquatic animals have gills. The lower terrestrial animals such as insects have pores on their body surfaces called spiracles while the higher animals have lungs.
- **Circulatory system :** An animal having an open circulatory system contains body fluid flowing through sinuses instead of vessels. The body fluid can be colourless (insects), bluish colour because

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of copper containing pigment haemocyanin (prawn and snails) or red colour because of the iron pigment haemoglobin. Animals having closed circulatory systems have blood as body fluid that flows through blood vessels after being pumped by the heart.

- **Excretory system :** Animals differ widely in the composition of metabolic wastes and the way in which they excrete them. Animals based on their major metabolic waste product have further been classified into three types :
- **Ammonotelic :** These animals excrete ammonia as the major excretory product like bony fish , tadpoles of frogs, etc.
- **Ureotelic :** These animals excrete urea as the major excretory product like mammals , frogs, toads, etc
- **Uricotelic :** These animals excrete uric acid as the major excretory product like most of the aerial animals such as insects, birds, bats and reptiles to conserve water.
- Some animals have specially developed parts for excretion other than kidneys such as flame cells in flatworms and malpighian tubules in insects.
- **Development in animals :** Animals depending on the site of development of zygote , followed by fertilization have been classified into three types :
- **Oviparous :** These animals such as amphibians, reptiles and fish reproduce by laying eggs whether fertilization is internal or external. (as in fishes and frogs)
- **Viviparous :** These animals such as mammals give birth to their young ones. During embryonic development, they feed the embryo through placenta.
- **Ovoviviparous :** In these animals such as sharks , the fertilization and development is internal but for the development the embryo they rely on the yolk of an egg instead of its nourishment from placenta. In this, the eggs are hatched within the body. e.g. some snakes.
- **Phylum Porifera :** Sponges which are mostly marine except *Spongilla, Euspongia* (Bath sponge) and others like *Euplectella* (Venus flower basket) constitute the phylum Porifera.
  - These are exclusively aquatic sessile metazoans (multicelled immobile animals) that have water intake and outlet openings, called ostia and large osculum connected by chambers lined with choanocytes, cells with whip-like flagella.
  - All living sponges can remould their bodies, as most types of their cells can move within their bodies and a few can change from one type to another.
  - Sponges do not have nervous, digestive or circulatory systems.

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— Their bodies consist of a non-living jelly-like mass sandwiched between two main layers of large and varied populations of cells such as Lophocytes (amoeba) like cells that move slowly through the mesophyl and secrete collagen fibres, Chanocytes - the collagen-producing cell, Sclerocytes secreting the mineralized spicules ("little spines") that form the skeletons of sponges, oocytes and spermatocytes are reproductive cells.

- **Phylum Coelenterata :** It encompasses two animal phyla, the Ctenophora (comb jellies) and the Cnidaria (coral animals, true jellies, sea anemones, sea pens and their allies).
  — All coelenterates are aquatic, mostly marine with body form that is radially symmetrical.
  — The body has a blind sac-body plan with body cavity called coelenterons and a single opening, the hypostome. It is surrounded by sensory tentacles equipped with either nematocysts or collobasts to capture prey.
  — Digestion is both intracellular and extracellular; respiration and excretion are accomplished by simple diffusion. A network of nerves is spread throughout the body.
  — Many forms exhibit polymorphism (Alternation of generation), wherein different types of individuals are present in a colony for different functions. These individuals are called zooids, polyps (vegetative) and medusae (reproductive)
  — These animals generally reproduce asexually by budding, though sexual reproduction does occur in some groups. The life cycle shows a kind of alteration of the generations called metagenesis.
- **Phylum Platyhelminthes :** It's a phylum of relatively simple bilaterian, unsegmented, soft-bodied invertebrates.
- They are acoelomates with no specialized circulatory and respiratory organs. They gain oxygen and nutrients by diffusion, and hence, are dorsoventrally flat.
- The digestive cavity has only one opening for both ingestion (intake of nutrients) and egestion (removal of undigested wastes); as a result, the food cannot be processed continuously.
- They are of two types Cestodes (tapeworms and free-living form like Planaria) and trematodes (flukes like Trematoda and Digenea) with complex life-cycles. Cestodes generate vast numbers of hermaphroditic, segment-like proglottids that detach when mature, are excreted, and then release eggs.
- **Phylum Aschelminths :** also called Nemathelminthes, are pseudocoelomates, mostly parasitic .
  — The body is long, cylindrical, fusiform (pointed at both the ends) with the body wall composed of cuticle, epidermis and musculature.

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— The digestive system is complete and respiration takes place by simple diffusion.
— They have body cavity, called pseudocoel, which is filled with pseudocoelomic fluid.
— The nervous system consists of a nerve ring and many longitudinal nerve cords. i.e. circumpharyngeal ring.
— Only reproduces sexually with sexual dimorphism. Males are usually shorter than females such as in roundworm (Ascaris) and filaria worm. Males are carriers of a single testis that opens into cloaca. In females, ovaries, oviducts and uteri are double.

Worms and diseases caused by them : *Enterobius vermicularis* (Pinworm disease), *Ascaris lubricoides* (Roundworm disease), *Wucheria bancrofti* (Filariasis/Elephantiasis), *Taenia solium* (Pork tapeworm disease), *Fasicola hepatica* (Liver infection), Rhabditis, Trichinella etc.

➢ **Phylum Annelida :** It includes segmented worms like earthworms and relatives leeches and marine forms called polychaetes.

➢ **Polychaetes** include worms such as fireworms, bristle worms, clam worms and sea mice. Each has a specific larval stage called **trochophore** which sinks to bottom before development into a complete worm.
— These are bilaterally symmetrical, triploblastic, coelomate, (first animals to have true coelom) invertebrate organisms with parapodia for locomotion.
— **The earthworm** an Oligochaeta has a sticky pad in the roof of the mouth. Most of the earthworms are burrowers that feed on wholly or partly decomposed organic materials. An earthworm is also characterized by the presence of a dark red band called clitellum in 14-16 segments.
— Hirudinea with best-known members as leeches are mostly blood-sucking parasites, mainly on fish in water and cattle on land. They have suckers at both ends of their bodies, which they use to suck blood and in their locomotion like inch worms.
Oligochaetes are full hermaphrodites and produce a ring-like cocoon around their bodies, in which eggs and hatchlings are nourished until they are ready to emerge.

➢ **Phylum Arthropoda :** It includes invertebrate animals having exoskeletons (external skeletons), asegmented bodies with cuticle made of chitin and jointed pair of appendages . The presence of cuticle makes them undergo moulting from time to time.
— They are bilaterally symmetrical with true coelom.
— They have tubes in tube system with mouth and anus. The mouth has five distinct mouth parts for different types of ingestion practices followed from sucking to biting.

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— Their nervous system includes a brain and ganglia, respiratory system is in the form of tracheae and spiracles and lacunnar circulatory system with a simple heart, one or more arteries, and no veins. A cockroach has a set of is 13 open hearts attached to its abdominal walls with ciliary muscles for open circulation.

- Reproduction normally sexual with evident sexual dimorphism.and gonochoristic, but can also be parthenogenetic.

— The phylum includes insects, arachnids, myriapods, and crustaceans.

- **Insecta :** The largest class of arthropoda includes arthropods which have a chitinous exoskeleton, a three-part body (head, thorax and abdomen), three pairs of jointed legs, compound eyes and one pair of antennae.
- The mouth parts include labrum, mandible, maxillae , labium and hypopharynx.
- **Arachnids :** These include arthropods with eight pairs of jointed legs like scorpions, spiders, ticks and mites.
- **Myriapods :** These include the members of phylum arthropoda with a multiple number of legs ranging from 750-10,000 such as in centipedes and millipedes.
- **Crustaceans :** Most crustaceans are free-living aquatic arthropods, but some are terrestrial (e.g.wood lice); some are parasitic (e.g. rhizocephala, fish lice, tongue worms) and some are sessile (e.g. barnacles). These also include crabs, lobsters, crayfish, shrimp, etc.

Phylum Mollusca : Their characteristic features include :

— Unsegmented, coelomate with soft body and bilateral symmetry

— Presence of an internal or external shell except in case of an octopus which lacks an external shell.

— Presence of toothed tongue (made mostly of chitin) called the radula , mantle which is a fold in the body wall that lines the shell and muscular foot or tentacles in some for locomotion.

— Presence of a complete digestive tract starting with the mouth and ending with anus.

— With the exception of cephalopods all molluscs have open circulatory systems as the blood circulates between gills and heart via the blood-filled space haemocoel. In some cases, the blood is blue in colour such as in pila.

— Excretion is carried out by a pair of nephridia, which empty their contents into the mantle cavity.

— The basic pattern of reproduction is one of having separate sexes, but several snails are hermaphrodites.

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Apple snail (Pila), Octopus (Apex fish), Mother of Pearls (Katal fish), Marine rabbit (Aplesia), Horticulture lobster(Kunlini) , Cuttle fish (Sepia), Butterfly chiton and sea star (Cryptoconchus)

- **Phylum Echinodermata :** Free living exclusively benthoic marine (living at the bottom of sea or ocean) forms such as star fish, sea urchins, brittle stars, sea cucumbers and sea lilies sand dollars etc. with adults being radially symmetrical and larvae bilaterally symmetrical.
  - The body is represented by a central disc covered by ossicles with spines called pedicellaria. It may bear extensions called arms but all have water vascular systems.
  - The digestive system is complete, the nervous system has a central nerve ring with five radiating nerves.
  - They are truely coelomic, withont head.
  - They have poorly defined open circulatory system and no excretory system.
  - Tube feet are present for feeding, locomotion and respiration. Tube feet are extended and retracted by variation in hydraulic pressure of the fluid in them and contraction of their muscles.
  - Reproduction is sexual. Sexes are separate. Development is indirect.
  - Show very high power of regeneration, a characteristic feature called autotomy for self-defence.
- **Phylum Hemichordata :** These are the protochordates. They are distinguished by a tripartite (three-fold) division of the body with preoral lobe in front behind which is a collar and then last comes a trunk as clearly identifiable in *Balanoglossus (Tounge worm).* They are exclusively marine and possess characteristics common to chordates and non-choradates such as:
  - presence of branchial openings, or "gill slits," that open into the pharynx.
  - presence of rudimentary structure in the collar region, the stomochord, that is similar to a notochord.
  - presence of a dorsal nerve cord, in addition to a smaller ventral nerve cord.
- **Agnatha and gnathostomata :** These are the two super classes of subphylum vertebrata.
- Agnatha includes animals which lack jaws and paired appendages such as lampreys, hagfish.
- Gnathostomata has further been classified into five classes :
- **Class Pisces :** It includes all fish, fresh or marine water. However, based on the structural body plan, they have been classified into two major groups of chondrichythes and osteichythes.

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Chondrichythes v/s osteichythes :		
	Chondrichythes	**Osteichythes**
Habitat	Mostly marine	Both marine and fresh water
Endoskeleton	Cartilaginous	Bony
Scales on skin	Placoid	Cycloid or ctenoid
Gills	5-7 pairs	Only four pairs
Operculum	Absent	Present
Mouth	Ventral	Terminal
Swim bladder	Absent, cannot glide in water	Present, can glide in water.
Tail fin	Heteroceracal	Homoceracal

- **Chondrychythes :** Scolidon (dog fish), sharks, skates, rays like torpedo(electric ray fish) and recently discovered latimeria that interlinks amphibians and fish.
- **Osteichythes :** Rohu, Katla, Salmon, Trout, Sea Horse, etc.

Whales and Dolphins are not fish but aquatic mammals.

The eel is one of the fish that lives in an estuary, i.e. capable of living in both marine and fresh water.

- **Class Amphibia :** Amphibians are cold-blooded vertebrates. They have backbones and maintain their body temperature through external means, such as lying in the sun. Amphibians spend part of their life in water and part of their life on land surviving on insects. They have permeable skin, for gases and some molecules penetrate, they also have gills for some portion of their life when they undergo metamorphosis, as noticed in the stage of a tadpole Unlike other terrestrial animals, they lay shell less eggs, They also show a special courtship behaviour in which the male goes to the potential region and produces sound to attract the female partner. When females approach, males clasp them around the back and fertilize the eggs as they are deposited. However the act of fertilisation is external. However, salamanders do not vocalize for courtship.
- **Class Reptilia :** All reptiles are cold-blooded with skin covered in a horny epidermis, making it water-tight and enabling reptiles to live on dry land. Each reptile has a three- chambered heart consisting of two atria, one variably partitioned ventricle, and two aortas that lead to the systemic circulation. **Crocodilians have four-chambered hearts, similar to birds**, but also have two systemic aortas and are, therefore, capable of bypassing the pulmonary circulation.
- Most reptiles lay amniotic eggs covered with leathery or calcareous shells. Amnion, chorion and allantois are present during embryonic life. The eggshell protects the crocodile's embryo and keeps it from drying out, but it is flexible to allow gas exchange.

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- **Turtles** and tortoises are characterised by special bony or cartilaginous shells developed from their ribs and that act as shields. However, though neither of two have any teeth but beak like birds, tortoises mostly live on land with the life span of some 199 years or more while turtles live in water with a short life-span of 20-40 years.
- **Snakes :** They are classifed in order squamata, constitute the suborder Serpentes (or Ophidia) , entirely limbless reptiles with a large number of vertebrae. Their skin is covered with horny scales, shedded, usually several times a year. Their paired internal organs are arranged linearly rather than side by side, and only one lung is developed, except in members of the boa family, They have loosely jointed and extremely flexible jaws, lack ears and movable eyelids but have good vision. They cannot hear airborne sound waves, but can perceive low-frequency vibrations (100–700 Hz) transmitted from the ground to the bones of the skull. Snakes have forked tongues but no larynx or vocal chords still capable of producing a hissing sound. A snake moves by means of muscular contraction, which can produce several types of locomotion, the commonest types being undulation and straight-line movement aided by the ventral plates, elongated scales on the abdomen that overlap with their open ends pointing towards the tail. These plates are moved forward by means of muscles attached to the ribs.
- **Class Aves :** Aves, the Latin word for birds, is a class of bipedal, warm-blooded, toothless, feathered, winged vertebrates with horny beaks that are characterized by a number of features that facilitate flight:
  - they are all endothermic like mammals but lack sweat glands.
  - light weight skeleton with pneumatic bones and kneeled chest
  - streamlined shape of body with forelimbs modified as wings for flying.
  - high metabolic rate with a four-chambered heart.
  - unique digestive system with gizzard for grinding ingested grains and respiratory systems with double respiration to suit to their flying needs with air bladder.
  - all birds lay hard-shelled eggs with a fatty yolk to support their embryos.
  - Humming bird the smallest of all birds can fly both forward and backward.
- **Flightless birds :** These are birds that have evolved an inability to fly. There are over 60 existent species including the well- known ratites (ostrich, emu, cassowary, rhea and kiwi) and penguins. The smallest flightless bird is the inaccessible Island rail (length 12.5 cm, weight 34.7 g). The largest (both heaviest and tallest) flightless bird, which is also the largest living bird, is the ostrich (2.7 m, 156 kg). Ostriches are farmed for their decorative feathers, meat and their skins. Their egg is the largest cell.
- **Class Mammals :** There are more than 4,000 different species of mammals with the smallest being the hog-nosed bat which weighs

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0.05 ounce and the blue whale being the largest is about 100 feet long and weighs 150 ton. All mammals irrespective of their habitats share some common characteristics such as:

— they have vertebral coloumn or spines with seven vertebrae in their necks.
— they are endothermic, *i.e.* "warm-blooded," animals which regulate their own body temperate which allows them to live in almost every climate on the earth.
— have hair on their bodies.
— have external ears and middle ear with three bones malleus, incus and stapes. Other vertebrates possess only one middle ear bone, the stapes.
— their lower jaw consists of only one bone, the dentary, which joins the skull at the squamosal bone. The jaws of other vertebrates are composed of more than one bone.
— give birth to young ones, hence, have mammary glands to feed young ones.

Mammals have been divided into three subclasses :

- **Subclass Eutheria :** These are placental mammals such as antelope, deer, camels, pigs, cows, sheep, hippos, cats, pandas, polar bears, grizzly bears, rodents, etc.
- **Subclass Metatheria :** It includes marsupials with about 270 species of mammals whose young ones are born in an immature state. Most females have pouches such as opossums, kangaroos, wallaby, wombats and koalas, tasmanian wolf, honey possum etc.
- **Subclass Prototheria :** It includes only two families of mammals that lay eggs with leathery shells and nourish their young one with milk from belly pores. These are duck-billed platypuses and spiny ant eaters.

Virus : Discovered by Iwanosky, crystallized by stauley Miller. They are borderline of living and non-living being made up of protein layer called capsid investing a strand of nucleicacid.

- Viriod — Only a strand of nucleic acid
- Virion — Non-living being outside living host cell
- Virus — Living inside a living host cell

Phages and types

- Photophage — Plant virus
- Zoophage — Animal virus
- Bacteriophage — virus living in bacteria
- Coliophage virus — found in animal's colon.

Reteroviruses : Viruses with RNA as genetic material e.g. HIV and Polio viruses.

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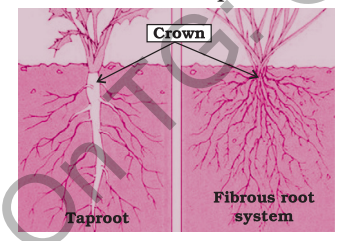
Chapter 4

PLANT STRUCTURE AND FUNCTIONS

Root and shoot system, type of plants: herbs, shrubs, trees , creepers, climbers, adventitious stems, roots, leaves and modification, flower; general structure and types, type of inflorescence, seed types , fruit types and their edible parts.

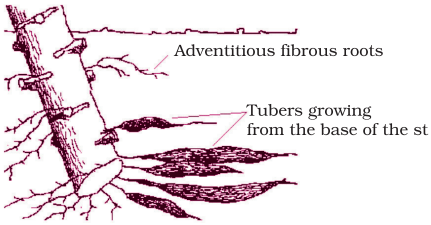
- **Smallest and largest plant :** The smallest flowering plant is Wolffia (0.1m) and the tallest tree is *Eucalyptus reguans* (114 m). The largest known crown of a tree is of *Ficus bengalensis.*

  A plant is known to posses two systems called shoot system and root system.
- **Root system :** The non-green plant structure that grows into the soil and anchors the plant to the ground for the absorption of water and minerals makes up the root system. It develops from the radicle of the embryo in a seed.
- **Types of root systems :** There are primarily two types of root systems called tap root system and fibrous root system.
- **Tap Root System :** The root develops from the radical and continues growing actively producing lateral branches. These are characteristic of most of the dicot plants.



Tap Root System and Fibrous Root System

- **Fibrous Root System :** It is the opposite of a tap root system being usually formed of thin, moderately branching roots growing from the stem that looks like a mat made out of roots when the tree has reached full maturity. A fibrous root system is universal in monocotyledonous plants, ferns and gymnosperms like coconut and palm.
- **Adventitious Root System :** Roots developed from any plant part other than the radical make up the adventitious root system.



Adventitious Root System

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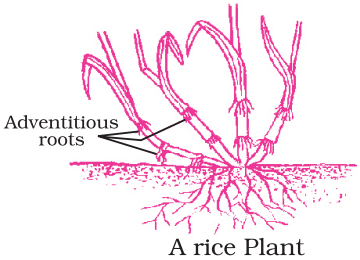

A rice Plant

- **Fusiform roots :** Swollen roots with tapering at both ends, e.g., radish.
- **Napiform roots :** Globular roots which taper abruptly, e.g., beet root, turnip.
- **Tuberous :** Roots with no definite shape, e.g., 4 O' clock plant.
- **Fasiculated roots :** These are storage roots which occur in a cluster, e.g, dahila, asparagus.
- **Beaded roots :** When roots are swollen at frequent intervals, e.g., bitter gourd.
- **Assimilatory roots :** Roots which develop chlorophyll and carry out photosynthesis, e.g., tinospora and trapa.
- **Haustoria :** They are the roots of the parasitic plants which penetrate the host tissue, e.g., in cuscuta.
- **Pneumatophores :** These are breathing roots which develop in plants growing in marshes such as rhizophora. They help in gaseous exchange for plant roots. These are mostly found in mangroves such as in Sundarbans in India.
- **Prop roots :** These are aerial roots that develop from the horizontal branches of a tree for providing additional support to the crown, e.g., Ficus tree (Bargadh).
- **Functions of a Root :** These include
  - — absorption of water and minerals from the soil
  - — providing anchorage to the plant for holding the soil firmly and in some cases, prop roots provide additional support to spreading tree branches.
  - — help in vegetative propagation of species, e.g., sweet potato.
  - — in parasitic plants, roots penetrate into the host stem to obtain food and water.
  - — storage of food such as in turnip and sweet potato.
- **Phreatophytes :** These are plants whose roots grow deepdown up to the depth of the water table for water absorption.
- **Plantless roots :** Rafflesia is a plantless root, *i.e.* it has roots only and lacks shoots, although it produces flowers during flowering stage.
- **Shoot system :** It comprises the longitudinal axis called stem upon which are borne the leaves, buds and reproductive organs of the plant.

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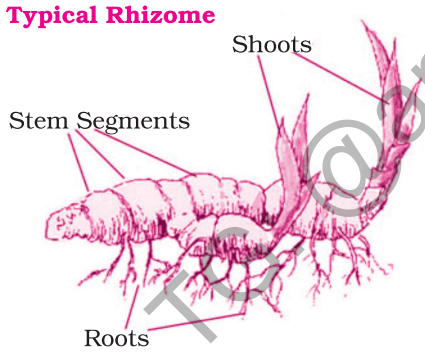
Shoot system

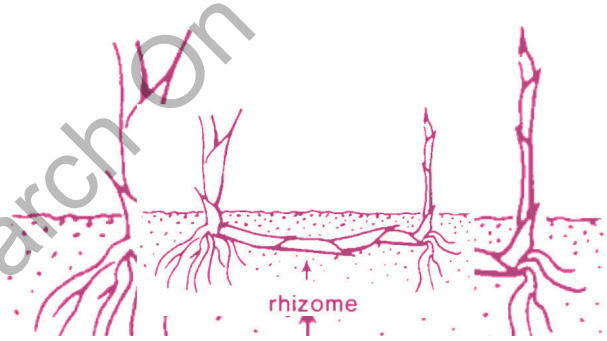
- Weak Stem
  - Trailers: Ipomea, Tridam.
  - Twiners: Clitaria, Mikenia.
  - Climbers: Grape, Bougainvillae
- Strong Stem
  - Branched: Mango, Guava,
  - Unbranched: Coconut, Bamboo

- **Modified stem :** Generally three ways exist in which the stem has been found to be modified.

  Underground modifications : These include:
- **Rhizome :** These are horizontally growing, fleshy, underground stems, e.g., ginger, turmeric, etc.

Typical Rhizome





Rhizome

- **Bulb :** Stem reduced to a disc-like structure, bearing concentric layers of fleshy leafy bases that comprise the food store, e.g., onion and garlic.
- **Tuber :** A swollen underground stem that contains stored food, and acts as an organ of perennation and vegetative propagation, e.g., potato.
- **Corm :** Short erect fleshy swollen underground stem, e.g. alocasia, colocasia.

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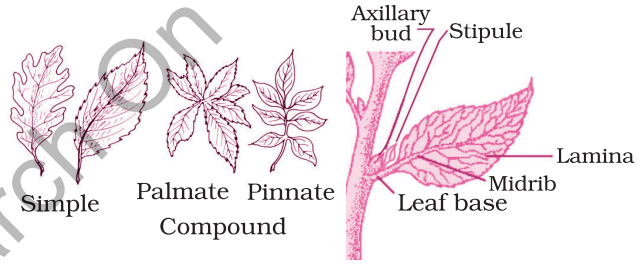
- **Tendrils :** These slender, spirally coiled structures develop from the axilary buds and help the plant to climb with support of firm structures e.g. watermelon, cucumber, pumpkines etc.
- **Subaerial Modifications:** These are of four types :
  Runner : e.g. Grass, Oxalis.
  Stolon : e.g. Jasmine, Strawberry.
  Offset : e.g. Water hyacinth, Pistia.
  Sucker : e.g. Rose, Chrysanthemum.
- **Special Modifications :** These are of five types:
  Stem tendril : e.g. Grapes, Cucurbita
  Thorns : e.g. Citrus, Bougainvillea.
  Phylloclade: e.g. Cactus, Cocoloba
  Cladodes : Ruscus, Asparagus.
  Bulbils : e.g. Aloe.
- **Phylloclade v/s Cladodes :** A Cladode is a stem, modified into a leaf-like structure for photosynthesis but phylloclade is a branch, modified into a leaf-like structure for photosynthesis.
- Although a phylloclade is a type of cladode yet both structures are different because phylloclades have several internodes functioning like a leaf, while cladodes only have one or two.
- **Leaf :** The flattened appendage of the stem that arises as a superficial outgrowth from the apical meristem, as initially it emerges from the shoot meristem as Primordia and then gradually grows older leaves are the chief photosynthetic organs of the plant. Collectively leaves constitute the foliage of the plant.
- **Simple Leaves :** A leaf is said to be simple when its lamina is entire or is incised, the incision does not touch the midrib.



- **Compound leaves :** A leaf is said to be compound when its lamina is completely divided into distinct segments or leaflets. These leaves may be of two types : Pinnate and Palmate
- **Palmate Leaf :** It is a compound leaf that has smaller leaflets attaching to a common central point. The whole structure is "palm-like" and shaped like the palm of a hand.
- **Pinnate Leaf :** It is a compound leaf that attaches to the stem and is divided into smaller leaflets. It can either be even or odd, which is the amount of leaflets contained on the leaf.
- **Modifications of Leaves**
  Leaf Tendrils : e.g. Sweep pea, Wild pea.
  Leaf Hooks : e.g. Bignonia unguis – cacti

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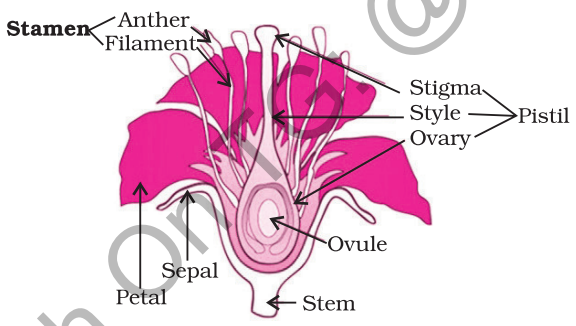
Leaf Spines : e.g. Berberis, Opuntia, cacti
Leaf Scales : e.g. Asparagus, Ruscus
Phyllodes : e.g. *Acacia moniliformis, Parkinsonia aculeata.*

- **Functions of Leaves -** These include:
  — Manufacture of organic food through photosynthesis
  — Gaseous exchange that takes place through stomata, responsible for transpiration (loss of water in form of water vapour)
  — In Insectivorous plants, leaves are modified into insect-traps such as in the pitcher plant and venus-fly trap while in some plants, leaves store water to resist drought.
  — For storage of food, as in fleshy leaves in onion.
  — In some plants such as Bryophylum, the leaves bear buds for vegetative propagation.
- **Largest and broadest leaf :** Plant with the largest leaf is *Raphia regalis* (10-15m) and with the broadest leaf is *Victoria amazonica* (1.5 to 2m).
- **Phyllotaxy :** The arrangement of leaves in a plant is called phyllotaxy.
- **Flower :** A flower described as the reproductive appendage is the characteristic reproductive structure of an angiosperm with modified floral leaves.

Parts of a Flower



- **Largest bud :** The cabbage is the largest bud in a plants.

Basic Structural Plan of Flowers

- Pedicel is the stalk of the flower. Sepals are green, leaf-like structures that arise from thalamus at the base of a flower and form the outermost circle of appendage providing protection to floral parts during bud stage. They are collectively called Calyx.
  -The whorl of appendages that arise inner to sepals are of petals. They are mostly brightly coloured to attract insects for pollination and produce fragrance. They are collectively called corolla.
- The third group of appendages consists of stamens. They collectively called the androecium are male reproductive organs. Each stamen consists of a slender stalk, the filament and the tetragonal bilobed anther except in case of family Malavceae.
- The centre of the flower contains the female reproductive whorl called the gynoecium or pistil, representing the female reproductive organ. Pistil is composed of one or more carpels while each carpel consist of three parts — Stigma, Style and Ovary.

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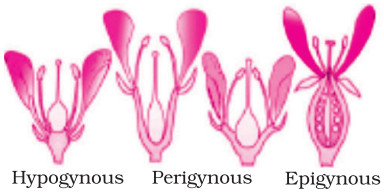
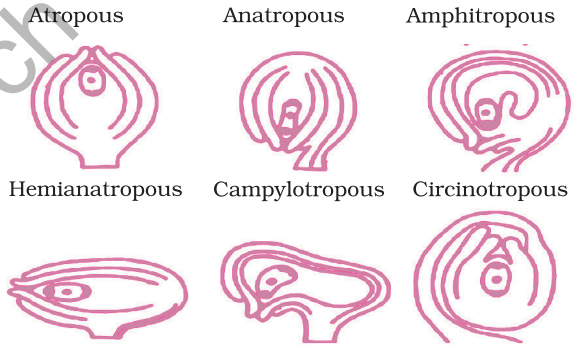
- Inside an ovary, the ovules develop attached to the placenta. After fertilization in sexually reproducing plants , the ovule develops into a seed and the ovary into a fruit. In flowering plants, an ovule is seven-celled and eight-nucleated structure.
- **Flower types based on position of floral parts :**



Flower

Hypogynous	Perigynous	Epigynous
Gynoecium is present above other floral parts. Ovary is superior, e.g. brinjal, china rose, tomato, mustard.	Gynoecium is present at the centre. All other floral parts are at the same level. Ovary is half inferior, e.g., rose,	Ovary fused with thalamus. All other floral parts above gynoecium ovary is inferior, e.g., apple, cucumber.

- **Hermaphrodite :** Flowers that contain both stamen and pistil (bisexual flowers). i.e. both androecium and gynoecium.
- **Types of ovules :** Ovules in ovary based on the position of micropyle with respect to position of funiculus have been classified into six types as shown in the figure given below:



Types of Ovules

- **Monoecious :** Plants that bear the flowers of both sexes, e,g, maize.
- **Dioecious :** Denoting a plant species in which male and female flowers are borne on separate individuals, e.g., papaya.

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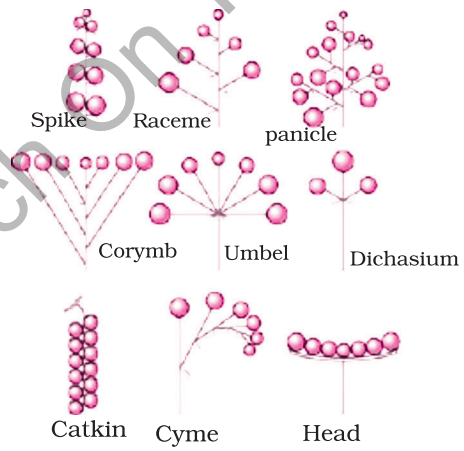
- **Strobilus kunthiana (Neelkuranji) :** It's a plant that flowers after every 12 years.
- **Inflorescence :** The arrangement of the flowers on the floral axis is known as inflorescence. Morphologically, it is the part of shoot. The stem holding the whole inflorescence is called a peduncle and the major axis holding the flowers or more branches within the inflorescence is called the rachis. The stalk of each single flower is called a pedicel. Bamboo plants. Flower after more than 12 years and die soon after flowering.
- **Solitary flower v/s floret:** A flower that is not part of an inflorescence is called a solitary flower and its stalk is also referred to as a peduncle. Any flower in an inflorescence is called a floret.
- **Types of inflorescence :** An inflorescence can be racemose or cymose type.
- **Racemose Inflorescence :** It is indeterminate and unbranched type of inflorescence. In racemose type, new flowers are generated laterally, in acropetal succession. There is no definite determination and the axis never terminates in a flower, e.g., Snapdragon.
- **Cymose Inflorescence :** It is a determinate and branched type of inflorescence in which inflorescence axis terminates in a flower. Lateral branches of the flower develop below the terminal flower; each branch ends in a flower. They also produce lateral branches. Every axis terminates in a flower.
- **Types of racemose inflorescence :** The different types of racemose inflorescence include :



- **Simple Raceme :** It has a long peduncle and bears on a number of pedicellate flowers in acropetal succession, e.g., *Crotalaria, Erythrina.*
- **Panicle :** It is a branched raceme. The peduncle produces a number of branches in acropetal succession. On these branches, pedicellate flowers are produced in acropetal succession, e.g., *Mango.*

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- **Spike :** It has a long peduncle bearing a number of sessile flowers in acropetal succession, e.g., *Amaranthus.*
- **Catkin :** It is a type of spike inflorescence with a pendulous peduncle. The flowers are generally unisexual. e.g. *Acalypha, Mulberry.*
- **Spadix :** It is a type of spike with a fleshy peduncle and usually unisexual flowers. It is always accompanied by a big bract called spathes that almost covers the spadix, e.g., *Aroids*, Araceae, Palmaceqe family.
- **Corymb :** It is a racemose inflorescence with a slightly shortened axis. The older flowers have the longer and the younger flowers have the shorter pedicels so that flowers may be found more or less at the same level of arrangement, e.g., *Caesalpinia., Candytuft.*
- **Umbel :** It is also a type of racemose inflorescence whose main axis is shortened and at the tip bears a whorl of bracts. All the flowers are at the same level showing centripetal arrangement. An umbel inflorescence can be simple such as in Hydrocotyle or compound umbel as in coriander and carrot.
- **Types of cymose inflorescence :** There are different types of cymose inflorescence:
- **Simple Cyme** : It is a determinate inflorescence with a terminal flower that opens first and two opposite flowers below it.
- **Compound Cyme** : It is a branched cyme, determinate with each ultimate unit three-flowered.
- **Monochasial cyme :** It bears a terminal flower with one flower below. The branches may repeat many times to give a long coiled inflorescence, also known as helicoid cyme. The branch of this inflorescence can go in different directions.
- **Fruit :** It is a ripened ovary formed after the processes of pollination and fertilization which stimulates the ovary to develop into a fruit. The fruit consists of a fruit wall, the Pericarp, with epicarp – outer skin, mesocarp – sweet, edible fleshy layer and endocarp – innermost hard zone that encloses the seed.
- **True Fruits :** The fruit which is derived only from the single ovary of a single flower and in the development of which no other part outside the ovary takes part is called the true fruit, e.g., Mango.
- **False Fruit :** When apart from the ovary, other floral parts also take part in the formation of fruit, it is called as a false fruit, e.g., Apple, Banana.
- **Simple Fruits :** A simple fruit is the one in which only ovary takes part in development, e.g., Bean, Mustard,
- **Aggregate Fruit :** In an aggregate fruit, each free carpel develops independently to form a bunch of fruits, e.g., Strawberry, Custard apple.
- **Composite Fruit :** A composite or multiple fruit develops from an inflorescence by the fusion of florets and their parts, e.g., Pineapple.

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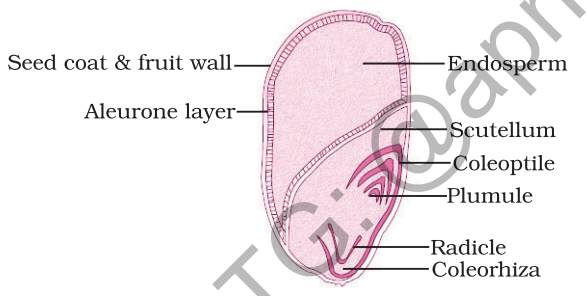
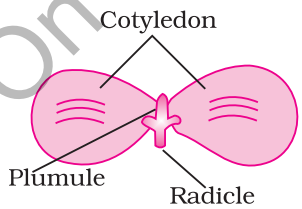
- **Common fruits with their types and edible parts**
  Fruits : Apple, Orange, Litchi, Mango, Gauva, Coconut, Tomato, Wheat and Maize, Banana.
  Type : Fleshy, Simple, Pome, Fleshy, Hesperdium, Simple Nut, Fleshy, simple, Drupe, Berry, Fleshy, simple, drupe Flesh, simple, berry Indehiscent, simple Cargopsis Fleshy, simple, gerry.
  Edible part : False fruit, fleshy thalamus Mesocarp and endocarp Fleshy Juicy aril: Mesocarp Thalamus and pericarp Starchy endosperm, mesocarp and endocarp
- **Parthenocarpic fruits :** Fruits without seeds. In them, the development of fruits takes place either without fertilization or from plant parts other than ovary such as apple and strawberry. These fruits are also called **false fruits**.
- **Seed :** It is the developed ovule formed after fertilization. It carries an embryo with radical, plumule and stored food in the form of endosperm.



Monocotyledonous Seeds



Dicotyledonous seed

- **Endospermic seeds (Albuminous) :** Seeds which possess a part of endosperm even after the development of an embryo. i.e. monocotyledonous seed.
- **Non endospermic :** (Non-albuminous) Seeds are non-albuminous. They do not carry any endosperm, instead they develop cotyledon. *i.e.* dicotyledonous seed.
- **Polyembryonic :** In some plants, the cells of other parts of ovary get involved in embryo formation, *i.e.* seed development. Such plants are polyembryonic like orange, lemon, etc. However, these seeds are non-viable *i.e.* they do not germinate or produce seedlings.

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Chapter 5

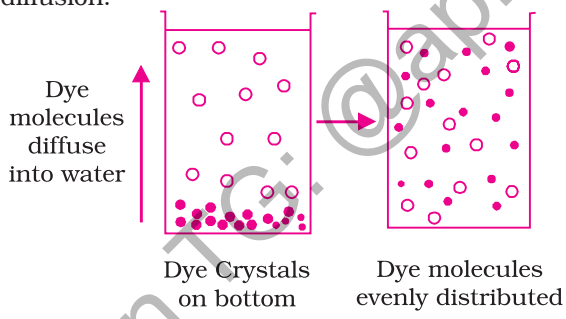
PLANT PHYSIOLOGY

Plant and water relations with respect to diffusion , osmosis and plasmolysis, transpiration and factors affecting it, mineral nutrition, plant hormones with their functions, plant movements: vernalization, photoperiodism, photosynthesis: cyclic and non-cyclic, photo-phosphorylation in light reaction, reduction of carbon dioxide in dark reaction, respiration: aerobic and anaerobic respiration, steps of cellular respiration.

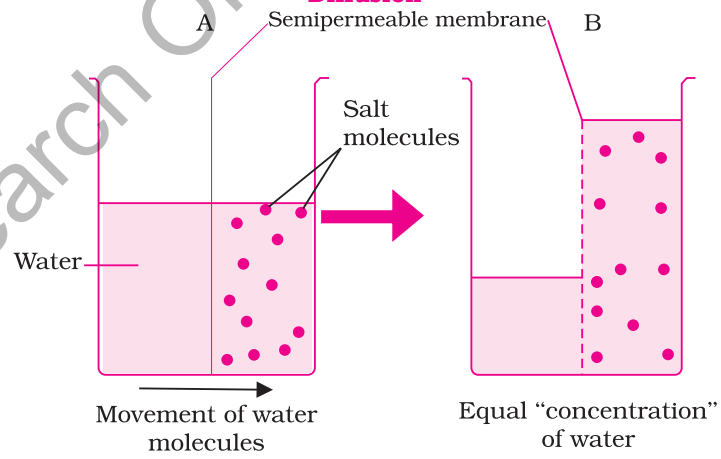
BIOLOGY

Transport in Plants

- **Diffusion :** It refers to the movement of molecules from the region of higher concentration to lower concentration against the pressure called diffusion.



Diffusion



Osmosis

- **Osmosis :** It is a special type of diffusion that involves the movement of solvent only across a semi-permeable membrane from a solution

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of low concentration, *i.e.* hypotonic solution to the solution of higher concentration, *i.e.* hypertonic solution across a semi-permeable membrane. In continues until an equilibrium is reached.

- **Osmotic pressure :** It is the pressure applied by a solution to prevent the inward flow of water across a semi-permeable membrane.
- **Osmotic potential :** It is the potential of water molecules to move from a hypotonic solution to a hypertonic solution across a semi-permeable membrane. Practically, both osmotic pressure and potential are the same.

Diffusion v/s Osmosis

Diffusion may occur with or without the presence of barrier against the concentration gradient for both particles of solute and solvent or even in the absence of water, *i.e.* solvent. But osmosis involves the movement of solvent particles only across a semi-permeable membrane.

- **Hypotonic and Hypertonic solution :** A hypotonic solution has higher water potential and low osmotic potential. Similarly, a hypertonic solution has low water potential but higher osmotic potential. It's the movement of water depending on the concentration of solution present in surroundings that a cell may undergo plasmolysis, *i.e.* shrinking of protoplasm (exosmosis) or the cell may become turgid with plenty of water (endosmosis).
- **Plasmolysis :** It refers to the shrinking of cell protoplasm because of exosmosis. The process of exosmosis causes loss of water, hence, used in food preservation or a marine organism cannot survive in fresh water or vice versa.
- **Absorption of water and its transport :** Pure water has a water potential of 0 MPa (ψ = 0 MPa). The addition of solutes lowers water potential (ψ = -0.2 MPa for instance) or an increase in pressure raises water potential for water absorption. Once the water enters into root hair cell partially by diffusion and osmosis each, the further movement of water up to xylem can be symplastic or apoplastic or both.
- **Symplastic v/s Apoplastic movement :** The symplastic movement involves the movement of water and solutes through the continuous connection of cytoplasm through plasmodesmata from cell to cell. It does permit any movement across the plasma membrane. Apoplastic movement is comparatively faster than symplastic movement involves the movement of water and solutes through the cell walls and the intercellular spaces, without crossing any membranes.
- **Transpiration pull :** A pulling or suction force developed in tracheids or vessels for the ascent of sap.
- **Ascent of sap :** A concept proposed by Dixon and Jolly describes the movement of cell sap, *i.e.* water with dissolved minerals from the root to the leaf through xylem without energy expenditure.

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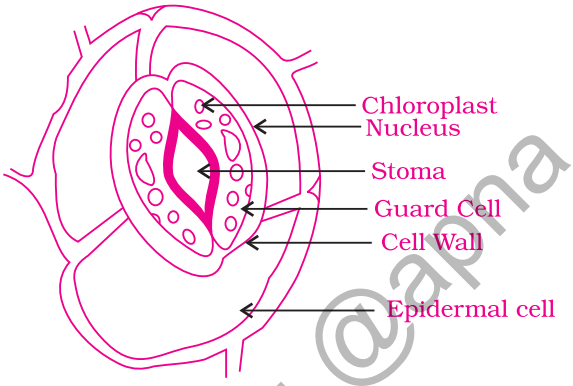
- **Stomata (singular-Stoma) :** These are minute pores found on the lower surface of leaves in dicot plants and on both the leaf surfaces, in monocot plants, through which transpriation occurs.
- **Guard cells :** These are a pair of cells present in a stoma. They are kidney-shaped (dicot plants) or dumble-shaped (monocot plants) investing a cavity called stomatal aperture. They control the opening and closing of stomata. As guard cells expand, the cavity opens for water to be lost in the form of water vapour along with the gaseous exchange that takes place simultaneously.



- **Transpiration :** The loss of water in the form of vapour through stomata from the leaves or lenticels in a tree trunk. About 90 percent of total transpiration occurs from leaves.
- **Factors affecting transpiration :** A number of factors affect the opening and closing of stomata, hence, the rate of transpiration *i.e.* temperature, wind velocity and atmospheric humidity. The maximum is at the high temperature, high wind velocity and low humidity conditions such as on a windy summer day.
- **Ganong's photometer :** A glass apparatus used for measuring the rate of transpiration. For simple study, Potato Osmometer is also used in laboratories.
- **Psychrometer :** It is an instrument used for measuring both relative humidity and rate of transpiration.
- **Photometer :** It is an apparatus used for measuring the rate of intensity of light. Which is also helpful to measure the rate of transpiration.
- **Porometer :** It is an apparatus used for assessing the relative sizes of stomata.
- **Gutation :** It's the loss of water in the form of liquid water droplets through hydathodes. It appears as a dew drop at the tip of a leaf.
- **Ascent of sap :** It involves transport of water and minerals through xylem under the effect of transpiration. It is passive process as does not involve any expenditure of energy in transport of water from root to leaf. Capillary forces support in above process.

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- **Translocation of solutes :** The transport of food through phloem, sieve cells or sieve tubes as proposed by Ernst Munch in Mass flow hypothesis from photosynthetic to non-photosynthetic regions is called the translocation of solutes. It involves energy expenditure in the transformation of sugar from one type to another. An insect therefore, feeding on cell sap gets sucrose as sugar. Also, we get cane sugar in the form of sucrose from sugar cane juice.

Green plants synthesize their food in the form of glucose, store it in the form of starch or fats but transport it in the form of sucrose through phloem based on concentration difference of sugar in the different regions of plants.

The translocation of solution through phloem can be demonstrated by girdling experiment.

Plant Hormones and their functions

- **Hormone:** It is a chemical substance produced in one part of the body that has a target elsewhere in the body. Plants have five classes of hormones. (Phytohormones):
- **Auxins :** Also called IAA (Indole acetic acid), promote stem elongation, inhibit growth of lateral buds (maintain apical dominance). They are produced in the stem, buds and root tips. Auxin is a plant hormone produced in the stem tip that promotes cell elongation and growth of lateral roots, hence, used as rooting hormone.
- **Apical dominance :** The cutting of the apical meristems to promote branching to have a bushy plant like in hedges, tea, etc. is called apical dominance. Auxin plays a role in maintaining apical dominance. Most plants have lateral (sometimes called auxillary) buds located at nodes (where leaves attach to the stem) as embryonic meristems maintained in a dormant state. Auxin maintains this dormancy. Once the apex of the shoot is removed, the auxin is no longer produced which, in turn, causes the lateral buds to break their dormancy and begin to grow and produce branches.
- Auxin is sprayed in fields and orchards to prevent premature leaves and fruit fall (abscission) and induce parthenocarpy.
- **Gibberellins :** Plant hormones known to promote stem elongation but excessive secretion, vertical growth makes the plant to grow tall but weak. It makes the plant more prone to logging by winds. However, for promoting the growth of internodes such as in case of sugarcane crop, its spray is adopted by farmers. Gibberellins promote germination and flowering also. It is also sprayed to reduce blossoming time of flowering, and process of sprouting of buds in vegetatively propagated plants.
- **Cytokinins :** These are hormones known to promote cell division. They are produced in growing areas, such as meristems at the tip of the shoot. Zeatin is a hormone in this class, and occurs in corn (*Zea mays*). Cytokinins also reduce apical dominance and cause delay in senescence.

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- **Abscisic Acid :** It is the hormone responsible for promoting seed dormancy by inhibiting cell growth. It is also involved in the opening and closing of stomata as leaves wilt. Commonly, considered as plant stress hormone being responsible for promoting early or premature leaf and fruit fall. It also increases the tolerance of plants to various kinds of stresses.
- **Ethylene :** A gaseous hormone produced by ripe fruits. Therefore, one bad apple spoils the whole bunch of apples. Ethylene is used for ripening crops at the same time. When sprayed on a field, it causes all fruits to ripen at the same time so that may be harvested together or used for ripening green raw bananas that come the from garden in the market for sale.

Plant Movements

- **Plant movements :** The higher plants show two types of movements called the tropic movements and nastic movements, based on the response to stimuli.
- **Tropic movements :** These are slow movements coordinated by hormones such as phototropism , geotropism, hydrotropism, etc. These movements are always towards the stimulus and donot affect the whole plant.
- **Phototropism :** The growth of a plant part towards light as stimulus is called phototropism. Auxin causes the curving of the plant stem tip towards the light. A plant movement has been shown and proved by F.W. Went through his Avena Curvature test.
- **Geotropism :** The growth of a plant part like roots towards gravity and away from light.
- **Hydrotropism :** The growth of a plant part towards water or moisture like roots. Therefore, roots are considered both positively geotropic and hydrotropic.
- **Siphanogamy :** It is the growth of a plant part in response to chemicals such as the growth of a germinated pollen tube in ovary towards the ovule through style.
- **Thigmotropism :** The movement of a plant part in response to touch such as in climbers.
- **Nastic movements :** These are sudden, fast movements that are, short- lived and against the stimulus such as in the touch me not plant (*Mimosa pudica*) the drooping of leaves on touching is a nastic movement, (Sesimonastic movement). These movements do not involve any hormonal role.
- **Nyctinastic movements :** These are movements in response to onset of darkness such in Oxalis, flowers open during day and close at night and vice versa in others which blossoms at night.
- **Vernalization :** The cold treatment of a plant to induce flowering is called vernalization. It shortens the vegetative phase of a plant life. It involves the conversion of certain hormone precursor florigen into flower-inducing active form florigen which under the influence of appropriate day-length induces flowering. Common examples of

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plants requiring vernalisation are winter rye, winter wheat, winter oat, winter barley, pea, beet, cabbage, henbane, chrysanthemum, viola, clover, etc.

- **Photoperiodism :** It is defined as the developmental responses of plants to the relative lengths of light and dark periods as proposed in 1920, by W. W. Garner and H. A. Allard *after their work on Nicotina tobaccum* Many flowering plants use a photoreceptor protein, phytochrome or cryptochrome, to sense seasonal changes in night length, or photoperiod, which they take as signals to a flower. Photoperiodism affects flowering by inducing the shoot to produce floral buds instead of leaves and lateral buds.
- **Long-day plants :** These plants flower when the night length falls below their critical photoperiod *i.e.* light period longer than a certain critical length as in summer. These typically flower in the northern hemisphere during late spring or early summer as days begin getting longer. In the northern hemisphere, the longest day of the year (summer solstice) is on 21 June after which days grow shorter and nights longer until 21 December (winter solstice). This situation is reversed in the southern hemisphere.
- **Short-day plants :** These plants flower when the night lengths exceed their critical photoperiod. They cannot flower under short nights or if a pulse of artificial light is shone on the plant for several minutes during the night. They require a continuous period of darkness before floral development can begin.
- These plants flower as days grow shorter and nights longer, *i.e.* after 21 June in the northern hemisphere.
- **Day-neutral plants :** These plants do not initiate flowering based on photoperiodism. Instead, they initiate flowering after attaining a certain overall developmental stage or age, or in response to alternative environmental stimuli.

  Some of long-day obligate plants : Carnation (*Dianthus*) and Oat (*Avena*)

Some long-day facultative plants : Pea (*Pisum sativum*), Barley (*Hordeum vulgare*), Lettuce (*Lactuca sativa*) and wheat (*Triticum aestivum*).

Some short-day facultative plants : Ganja (*Cannabis*), Cotton (*Gossypium*), Rice (*Oriyza*)

Jowar **(Sorghum bicolor) :** Green Gram (Mung bean) and Soybeans (*Glycine max*).

Day-neutral plants : cucumbers, roses and tomatoes,

Mineral Nutrition in Plant

- **Plant Nutrition :** A total of seventeen essential mineral elements are required for the normal growth of plants. These essential elements include ten macronutrients and seven micronutrients.
- **Macro-nutrients :** Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Potassium, Magnesium, Sulphur, Calcium, Silicon.

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- **Micro-nutrients :** Boron, Copper, Manganese, Zinc, Molybdenum, Iron Chlorine and Nickel being the last element to be discovered in the list of essential elements.
- **Useable forms of nitrogen :** Higher plants utilise nitrogen in the oxidised forms such as nitrate (NO_3^{1-}) and nitrite (NO_2^-) or in the reduced form (NH_4^+).
- **Biological nitrification :** It is the mode of nitrogen fixation caused by nitrogen fixing symbiotic bacterium Rhizobium in the roots of legume plants, Cyanobacteria (Nostoc, Anabena and Oscillatoria).
- **Nitrosomonas and Nitrosococcus :** In nitrogen fixation, the dinitrogen of the atmospheric air is first reduced to ammonia with the help of enzyme nitrogenase and then these soil bacteria convert ammonia or ammonium ions (NH_4^+)to nitrite (NO_2^-) ions and later into nitrate (NO_3^-) ions to be absorbed by plants. The conversion of ammonium to nitrite is carried out by the bacteria Nitrosomonas and that of nitrite to nitrate by nitrobacter.
- **Insectivorous plants :** In soils deficient in nitrogen, the growing plants are mostly found to be insectivorous such as Nepenthes (Pitcher plant). They have modified their different body parts to trap insects, kill them and obtain nitrogen to fulfil their nitrogen requirements. Drosera, Utricularia, (Bladder wort), Cyclops , Venus fly trap and Pingucula are different insectivorous plants.

Mineral nutrients, form in which they are absorbed, their functions and major deficiency symptoms -

Element	Obtained as from soil	Regions of plant in which required	Functions
Sulphur	SO_4^{2-} (Sulphate)	Stem and root tips young leaves remobilised during senescence	Constituent of certain proteins, amino acids) vitamins (thiamine,biotin, CoA) and ferredoxin; (cysterine and methionine) Deficiency causes chlorosis, leaf curls, woody stems.
Iron	Fe_3^+ (Ferric ions)	Everywhere; collects along leaf veins	Constituent of ferredoxin and cytochromes; Activates catalase; required for the synthesis of chlorophyll; Activates certain enzymes (carboxylases).
Molybdenum (trace)	MO_3^+ or MO_2^{+2} MoO_2^{2+} (molybdate ion)	Everywhere; MO_3^+ particularly in roots	Activates certain enzymes in nitrogen metabolism; Deficiency causes chlorosis and appearance of grey spots on leaves. (nitrogen deficiency)

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Boron	Boron or borate ions BO_3^{3-} or $B_4O_7^{2-}$	Leaves and seeds	Required for uptake and utilisation of $Ca2^+$, pollen germination and cell differentiation, carbohydrate translocation. Deficiency causes a general retardation of growth. (Brown, heart disease)
Copper (trace)	Cu^{2+} (cupric ion)	Everywhere	Activates certain enzymes. Deficiency causes necrosis of tip of young leaves (die back of shoots).
Zinc (trace)	Zn^{2+} (zinc ion)	Everywhere	Activates various enzymes especially carboxylases, part of carbonic anhydrase and various dehydrogenases, needed for auxin synthesis. Deficiency causes die back of the shoot.
Chlorine	Cl^- chloride anion	Everywhere	With Na^+ and K^+ helps determine solute concentration and anion-cation balance; essential for oxygen evolution in photosynthesis. Deficiency causes wilted leaves, reduced flowering and fruiting.
Nitrogen	NO_2^-, NO_3^- or NH_4^+	Everywhere particularly in meristematic tissues	Constituent of proteins, nucleic acids, vitamins, hormones, coenzymes, ATP, chlorophyll. Deficiency causes retarded growth, late flowering.
Phosphorus	$H_2PO_4^-$ or HPO_4^{2-} (phosphate ions)	Younger tissues, withdrawn from older, metabolically less active cells	Constituent of cell membrane, certain proteins; all nucleic acids and nucleotides; required for all phoshphorylation reactions. Deficiency causes stunted growth and chlorosis delay in germination of seeds, premature fall of leaf and flowerbuds.
Potassium	K^+	Everywhere	Helps maintain an ionic balance in cells; involved in protein synthesis; formation of ATP, nucleic acid, cell membrane and in opening and closing of stomata; increases hardiness; acti-vates enzymes and helps in the maintenance of the turgidity of cells.

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Calcium	Ca^{2+}	Everywhere	Involved in selective permeability of cell mem-branes, activates certain enzymes; Deficiency causes yellow edges to leave and their premature death.
Magnesium	Mg^{2+}	Meristematic tissues; buds, leaves, root tips, accumulates in older leaves and later withdrawn from ageing leaves and exported to developing seeds	Required for the development of stem and root apex, and as calcium pectate in the middle lamella of the cell wall; Activates enzymes in phosphate metabolism and in synthesis of DNA and RNA constituent of chlorophyll; maintains ribosome structure; Deficiency causes an acute chlorosis and yellowing of all leaves

- **Hydroponics :** The water culturing of plants to study the importance of different mineral nutrients. (Goerick ,1940)
- **Chlorosis :** It is the yellowing of leaves because of the lack of chlorophyll.
- **Necrosis :** It is the development and appearance of dead brownish or greyish spots on the surface of leaves.
- **BMR :** It refers to basal metabolic rate (BMR) that involves the minimum rate of energy conversion required to stay alive.
- **Chelating agents :** These are chemical elements which keep a metal in soluble state like EDTA (Ethylene diamine tetra acetic acid).
- **Dieback condition :** It is the condition in which the death of foliage occurs from shoot tip to base.
- **Stunted growth :** It refers to the growth of a shoot or root less than normal.
- **Exanthema :** It refers to the splitting of a tree bark.
- **Leaching :** Washing down of minerals into soil making it deficient in N,P and K, the critical elements.
- **Mottling :** It refers to the appearance of colourless patches irregular marks, spots, blotches on leaves.
- **Heart rot :** It's the condition in which the inside tissue becomes soft due to disintegration and degeneration and decay in the centre of trunk.
- **Leghaemoglobin :** It is red-colour pigment found in root nodules of leguminous plants as a result of rhizobium-legume complex.
- **Tracer elements** are the atoms of elements called isotopes, They differ in atomic weights but not in chemical properties, Examples, C^{14}, O^{18} and P^{32} introduced in plant body to study metabolism.
- **Molybdenum :** It is the micro–nutrient required by plants in the least quantity.
- **Auxanometer :** An instrument developed by J.C.Bose to measure the vertical plant growth.

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- **Equisetum :** Presence of gold which has been reported to occur in its stem.

Photosynthesis

- **Photosynthesis :** It is chemically a redox reaction that involves the oxidation of water and reduction of carbon dioxide to produce sugar. It is the only source of energy for all organisms as all organisms directly or indirectly depend on the food synthesized by the green plants.

As quoted in Bible "All flesh is grass."

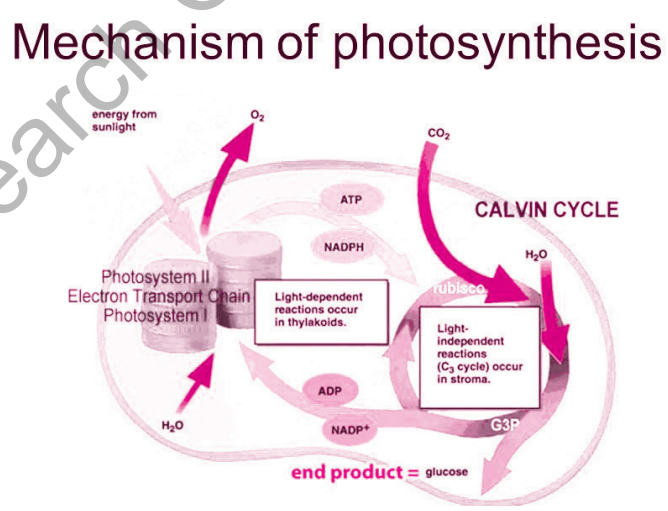
$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- **Photosynthetic pigments :** The plant pigments known to play role in photosynthesis, in absorption of sunlight are called photosynthetic pigments. These include chlorophyll, carotenes and xanthophylls.
- **Chromatography :** It is a separation technique used in separating the pigments.

The chromatogram for photosynthetic pigments shows orange for carotene at top followed by yellow colour of xanthophylls, blue-green for chlorophyll-a and olive green for chlorophyll-b at the bottom, i.e. the order from botton to top is:

Chlorophyll-b → Chlorophyll-a → Xanthophyll → Carotenes

- **Three steps of photosynthesis :** The absorption of energy by chlorophyll such that chlorophyll molecules get activated. The usage of the absorbed solar energy by chlorophyll molecules takes place in photo-phosphorylation and the reduction of absorbed carbon dioxide by hydrogen ions produced in dark reaction to produce a molecule of sugar.



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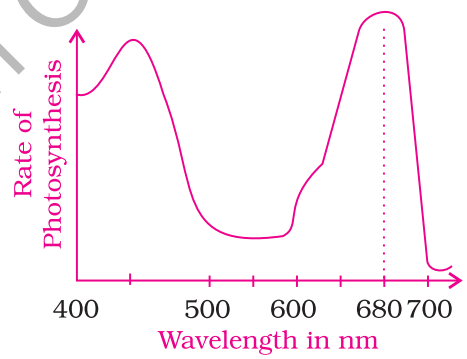
- **Photo-phosphorylation :** It refers to the formation of ATP that takes place in light reaction using solar energy. It occurs in the grana of the chloroplast.
- **Cyclic photo-phosphorylation :** It refers to ATP synthesis that can take place even if there is no carbon assimilation. In this process flow of electron is in the cyclic manner. Photolysis of water is not associated with this.
- **Non-cyclic photo-phosphorylation :** It always takes place prior to carbon assimilation and involves the photolysis of water for the required hydrogen ions resulting in the production of oxygen for its release as a by-product of photosynthesis. In this electron expelled from the pigment never comes back as there is continuous unidirectional flow of electron.
- **Colour of light and photosynthesis :** The rate of photosynthesis is maximum in plants exposed to a blue and red lights. Red light supports photosynthesis while blue light supports protein synthesis for required enzymes. Green light is mostly reflected hence, colour of leaves appear green.

  Similarly, the plant exposed to the intermittent period of light shows a higher rate of photosynthesis than plants exposed to a continuous period of light. It is merely because of the dependence of dark reaction on light reaction for energy and hydrogen ions.
- **Red drop effect :** The effect, first noticed by Robert Emerson of Illinois University, states that light of wavelengths beyond 680-700nm have insufficient energy to drive any part of photosynthesis. So, a huge drop in efficiency is noticed at 680-700nm. This phenomenon of a sudden drop in the rate of photosynthesis is called as red drop effect.



- **Quantum yield of photosynthesis :** It refers to the number of oxygen molecules released per light quanta absorbed by a plant.
- **Photo-oxidation :** The bright light and high temperature cause the burning of leaves, *i.e.* their oxidation. In plants , the photosynthetic pigments (carotenes) help to prevent photoxidation.

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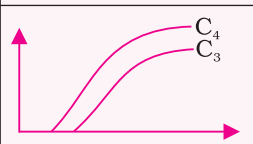
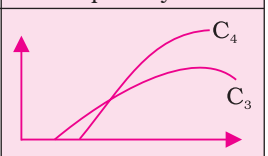
- **C-3 and C-4 plants :** On the basis of light effective in photosynthesis, a plant can be C-3 or C-4.

Difference in C-3 and C-4 plants	
C-3 plants	**C-4 plants**
These plants show Calvin cycle in which the acceptor of carbon dioxide is RuBP (Ribulose Biphosphate)	These plants show Hatch-cycle in which the acceptor of carbon dioxide is PEP (Phosphoenol pyruvic acid)
The first stable compound is 3-carbon compound, 3-PGA (Phosphoglyceric acid)	The first stable compound is 4-carbon compound, OAA (Oxaloacetic acid)
These plants cannot operate in the low concentration of carbon dioxide. They need stomata to open and close.	These can operate in very low concentration of carbon dioxide and do not need the stomata to open.
They are not characterized by the presence of Karanz anatomy and bundle sheath cells.	They are characterized by the presence of Karanz anatomy and bundle sheath cells.
They are not photosynthetically very efficient.	These plants are photosynthetically more efficient with the improved efficiency of carbon dioxide fixation.
About 95% per cent of all green plants are C-3 plants.	These include plants like grasses, sugar cane, millet, sorghum and maize.

Graphical comparison of C-3 and C-4 plants

Rate of photosynthesis	Rate of photosynthesis	Rate of photosynthesis
		
Ligh intensity	CO_2 conc. (ppm)	Temperature

- **Photorespiration :** It is defined the process of respiration *i.e.* oxidation initiated in chloroplast during the day due to high temperature is known as photorespiration. It is as the energy consuming light dependent uptake of oxgen and output of carbon dioxide. It involves an increase in oxygen uptake more than carbon dioxide and hence, has inhibitory effect on photosynthesis.
- **Effects of photorespiration :** The occurrence of photorespiration proved the decrease in photosynthetic rate with increasing light intensity after a certain limit and decrease in rate of photosynthesis

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with the increasing concentration of oxygen. It is also known as photosynthetic carbon oxidation cycle.

- **Crassulacean acid metabolism :** It is a modified form of CO_2 fixation in photosynthesis in succulent plants which keep their stomata close during day and open them at night. Hence, carbon dioxide uptake occurs in the dark. In these plants, CO_2 is fixed into an organic acid *i.e.* malic acid and is stored in cellular vacuoles until the energy from sunlight is available for photosynthesis in the day time.
- **Grana :** The site of light reaction in the chloroplast. In this reaction, O_2 is liberated by the photolysis of water along with the formation of ATP and 2NADPH as product.
- **Stroma :** The site of dark reaction in chloroplast in which CO_2 absorbed from the atmosphere is reduced by hydrogen ions produced in the light reaction to make carbohydrates. Only 0.2% of the light energy incident on the earth is utilised by photosynthetic organisms.
- **Chlorophyll-A :** It is the most active pigment as all the solar energy absorbed by the different photosynthetic pigments is passed onto the molecule of chlorophyll-A that actually initiates the light reaction,
- **Compensation point :** All green plants in the early morning or late evening hours do not undergo gaseous exchange in between the atmospheric air and the plant as the rate of photosynthesis equals the rate of aerobic respiration going on in a cell having both chloroplasts and mitochondria. This time of the day is called compensation point.
- **Starch test :** To verify the different factors affecting photosynthesis, starch test is performed on a selected plant part (mostly leaf). The test first involves the boiling of the selected plant part in water to break open the cells and then boiling the water boiled part in methylated spirit to remove chlorophyll. It's later when brown colour iodine is applied which in presence of starch gives blue-black colour, otherwise remains brown.

Respiration

- **Respiration :** It is the chemical breakdown or oxidation of (complex organic substances) to release the energy in the form of ATP. The cytoplasm and mitochondria are the site of respiration depending on its type based on the oxygen availability to a cell. Mitochondria are the site of aerobic respiration in which, energy-carrier molecules of ATP are produced, hence, called power house of the cell.
- **ATP :** Adenosine triphosphate is an energy rich organic compound which stores energy released during respiration. Therefore it is called as 'currency of energy'. The one ATP molecule hydrolysed gives rise to 7.3 Kcal energy.

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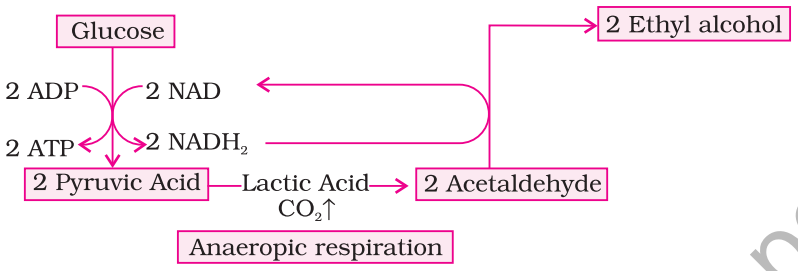
- **Anaerobic respiration :** Respiration which takes place in the absence of oxygen. The process can be represented through the following equation:

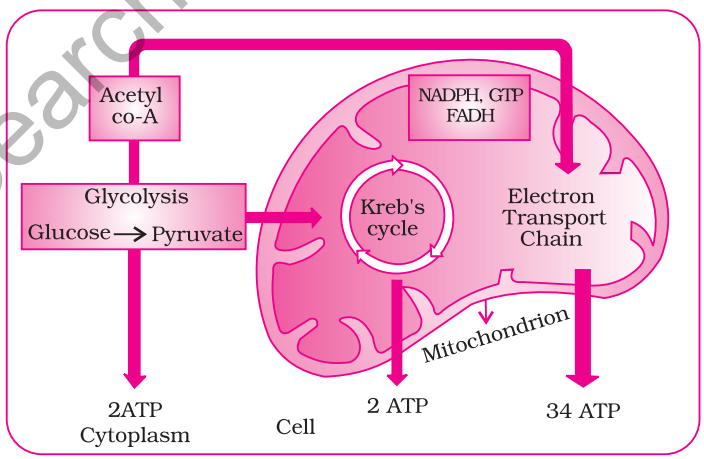


- **Fermentation :** It refers to the anaerobic breakdown of glucose producing ethanol and carbon dioxide. Commercially, the process being useful in bakery and brewery industry is carried out in air-tight closed containers using yeast. **The enzyme zymase from yeast catalyses the fermentation reaction**.
- **Aerobic Respiration :** Respiration which uses oxygen is called aerobic respiration. The process can be represented through the following equation:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38ATP.$$

(686Kcal/ 2870kJ)

- **Steps of aerobic reaction :** The whole process of aerobic respiration completes in three consecutive steps, each involving a number of changes before producing energy, rich molecules, ATP. These three steps include glycolysis in cell cytoplam, Kreb's cycle also called tricarboxylic acid cycle and ETS (Electron Transport System) and Oxidative phosphorylation. The later two take place in mitochondria.
- **Primary reaction :** The first step of the glycolysis that involves the conversion of glucose into Fructose1,6-diphosphate consumes ATP and is called primary reaction.



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- **Oxidative decaboxylation or link reaction :** It's the first reaction that marks the beginning of Kerb's cycle in mitochondrial matrix

  Pyruvic acid + CoA NAD^+ NADH Acetyl CoA + CO_2

- **Krebs Cycle (citric acid cycle /TCA cycle) :** This was elucidated by Hans Krebs in 1937. This is also known as Tricarboxylase Acid Cycle (TCA) In this, CO_2 and H_2O are obtained by breaking down of Pyruvate.
- **ETS :** It takes place in F1 particles. It actually involves the production of ATP and ends with the terminal oxidation, *i.e.* it is in the very last step of respiration that oxygen is required to oxidize the hydrogen ions obtained from water.

  $2H^+ + 2e^- + 1/2O_2 \longrightarrow H_2O$
- **Energy production :** In aerobic respiration a total of 38 ATP molecules are produced but out of these two are used up in glycolysis hence, the net production is of 36 ATP molecules from 1mole of glucose.

Total Energy output chart in respiration :	
Product	**ATP (Adenosine Triphosphate) equivalent**
Glycolysis	4ATP – 2ATP = 2ATP
2NADPH(H+)	6 ATP
Link reaction	2NADH(H+) 6 ATP
Kreb's cycle	6NADPH(H) + 18ATP
2GTP	2ATP
2FAD(H+)	4 ATP
Total energy output	36ATP

However, the net production of ATP is 38 – 2 = 36 as two ATPs are used up in primary reaction that takes place during glycolysis.

- **Respiratory Quotient (R.Q.) :** It refers to the volume of carbon dioxide liberated to the volume of oxygen consumed in respiration over a period of time.

  For carbohydrates, it is one : $6CO_2/6O_2 = 1$

  For fats, it is less than one : $57CO_2/80O_2 = 0.71$

  For proteins, it is about 0.9

  For organic acids, it is more than one : $4CO_2/3O_2 = 1.4$

  For alcoholic fermentation, it is infinity as no oxygen is involved in the process.

  For succulent plants, it is zero as there is no release of carbon dioxide with stomata closed.

  The produced carbon dioxide is used up in photosynthesis.

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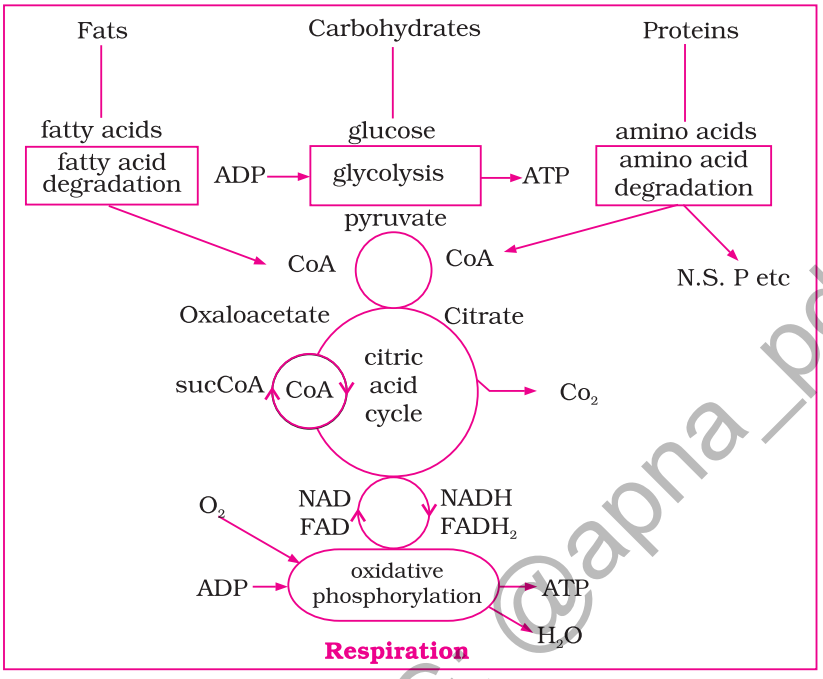

PLANT METABOLITES

- **Plant metabolites :** Plants are capable of synthesizing different types of organic molecules classified as primary and secondary metabolites.
- **Primary metabolites :** These metabolites are metabolic intermediates or products present in all living systems, essential for growth and life. These metabolites are involved in the primary metabolic processes such as respiration and photosynthesis.
- **Secondary metabolites :** These metabolites are metabolic intermediates or products that are not essential to growth and life. They are required for the interaction of plants with their environments and produced in response to stress. They have been divided into four classes: terpenes, phenolics, glycosides and alkaloids.
- **Terpenes :** These include compounds such as pyrethnoids, camphor, menthol, abscisic acid, rubber, taxol (Anti-cancer drug), b-carotene and gibberellin.
- **Phenolics :** These include simple phenols, acetophenone, coumarins, napthoquinone and flavonoids.
- **Glycosides :** These include saponins, known for their anti-inflammatory effects and cardiac glycosides known for inhibiting the activity of Na^+ - K^+ pump.
- **Alkaloids :** These include nicotine, caffeine, cocaine, morphine, codeine, etc.

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Chapter 6

HUMAN PHYSIOLOGY

Balanced diet, digestive system including ingestion, digestion, absorption and assimilation, respiratory system with inhalation and exhalation, gaseous exchange , cardiovascular system with working of heart, excretory system with role of liver and pair of kidneys, muscular system, endocrine system with hormones, nervous system: types, reflex action and sensory organs : eyes, ears and tongue with their structures and functions.

BIOLOGY

BALANCED DIET AND CONSTITUENTS

Balanced diet : A diet that satisfies the daily needs of a person is considered as a balanced diet. However, it varies from individual to individual being dependent on age, sex, body size, physical stature of body, daily routine, etc. However, a balanced diet for an average adult is made up of the following nutrients each day:

Nutrient	Quantity per day	Nutrient	Quantity per day
Energy	8,700KJ	Carbohydrates	310 g
Fats	70g	proteins	50 g
Sugars	90g	Sodium	2.3 g
Dietry fibres	30 g	Saturated	24 g
(Roughage)		fatty acids	
Vitamins	< 300mg	Minerals	5-10 g

The digestive system is uniquely designed to turn the food eaten into nutrients, which the body uses for energy, growth and cell repair. Roughage facilitates proper digestion and prevents constipation.

Major minerals and their sources	
Mineral	**Sources**
Calcium	Green leafy vegetables, grapes,watermelon, milk, dried fruits, sesame seeds, black beans.
Phosphorus	Milk, dried fruits, soyabeans, carrot, guava, dates
Iron	Green leafy vegetables, mango, apple, dates, sesame, grams, soyabeans, green gram, black beans, meat
Potassium	Garlic, radish, tomatoes, spinach, apple, milk, potatoes, milk, meats, whole grains
Sodium	Beetroot, garlic, French beans, table salt,milk, meat
Iodine	Sea food, iodized salt, onion etc.

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Magnesium	Guava, banana, radish, spinach, potatoes
Chlorine	Carrot, apricot, beetroot, cabbage, tomatoes,
(Chloride)	Banana, dates, table salt, milk, meat, etc.
Sulphur	Garlic, onion, beet root, radish, meat, fish, eggs
Manganese	Garlic, guava, cabbage, beetroot

— Milk and all other dairy products Vitamin-C and Iron.
— No food product has vitamin-D, if of plant origin.
— No food product has vitamin-C, if of animal origin.

Major vitamins and their sources

Vitamin	**Sources**
Vitamin A	Dairy foods, fruits and vegetables such as sweet potatoes, broccoli, cod and shark liver oil, egg yolk, carrot, spinach etc.
Niacin (B-3)	Poultry, fish and lean meats as well as eggs and nuts and dairy products like milk and cheese, leafy green vegetables, aspargus.
Thiamine (B-1)	Whole grain foods, peas, fish and lean meats, and some vegetables, yeast, dried beans.
Vitamin B12 Folic Acid	Meats, poultry, eggs and dairy products like milk Dark green leafy vegetables.
Pantothenic Acid & biotin	Whole grain cereals and broccoli and other cabbage-family vegetables.
Riboflavin(B-2) Pyridoxine(B-6)	Nuts, legumes, dairy products and lean meats Beans, nuts, eggs, fish, whole grains.
Vitamin C	All citrus fruits like oranges, lemons limes, and strawberries. Vegetables containing vitamin C which include turnip, greens, tomatoes.
Vitamin D	Dairy products like milk, butter and cheese, as well as cereals and fish, egg, yolk, chicken.
Vitamin E	Nuts and seeds as well as spinach and asparagus and other leafy green vegetables, as well as some vegetable oils, liver, egg, yolk etc.
Vitamin K	Green leafy vegetables like spinach, soyabeans and cabbage, milk.

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HUMAN DIGESTIVE SYSTEM

- **Dentition :** It refers to the development of teeth and their arrangement in the mouth. An animal whose teeth are all of the same type, such as most of non-mammalian vertebrates, i.e. fish, amphibians and reptiles, are said to have homodont dentition while those with different teeth types are called heterodont.

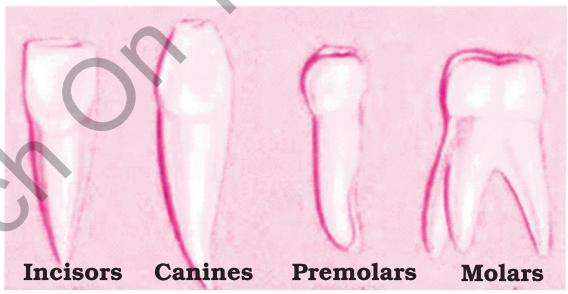
  Dentition and animals : The animals based on dentition can be:
- **Monophyodont :** These are animals with only one set of teeth throughout life such as herbivores like goats.

  Diphyodont : These are animals, with two successions of teeth (deciduous, permanent) such as humans.
- **Polyphyodont :** These are animals in which teeth are continuously discarded and replaced throughout life such as in kangaroos and elephants.

Types of teeth :

- Incisors – the sharp, chisel-shaped front teeth used for cutting food.
- Canines – sometimes called cuspids; these teeth are shaped like points (cusps) , used for tearing and grasping food.
- Premolars – these teeth have two pointed cusps on their biting surface for crushing and tearing food.
- Molars – these teeth with several cusps help chew (masticate) food.

Spiny ant eater (Echidna) and Whales have no teeth, such as the blue whale (*Balaenoptera musculus*) and the whalebone whale.



- **Dentition in humans :** Humans are diphyodont and heterodont. During their life time, they develop two sets of teeth called deciduous/ milk teeth and permanent teeth. There are total of 20 baby teeth , 10 of which are on the upper jaw and the other 10 on the lower jaw. A full set of adult teeth, on the other hand, contains an additional 12 teeth six more each on the upper and lower jaws. The new teeth are the first and second premolars and the third molars, more commonly known as the wisdom teeth. The first and second bicuspids erupt between ages 10 and 12. Wisdom (3rd molor) teeth don't erupt until ages 17 to 21.

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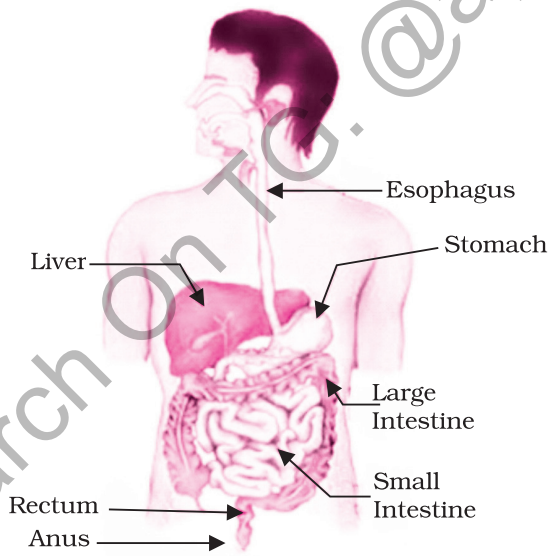
Dental formula (Milk teeth) $\frac{\text{I C P M}}{2.1.0.2 \atop 2.1.0.2}$

Dental formula (Adult teeth) $\frac{\text{I C P M}}{2.\ 1.\ 2.\ 3. \atop 2.\ 1.\ 2.\ 3.}$

- **Mouth :** The mouth is the beginning of the digestive tract where the digestion starts with the first bite of a meal. Chewing breaks the food into pieces that are more easily digested, while saliva mixes with food to begin the process of breaking it down into a form the body can absorb and use. After chewing , the roughly spherical ball-shaped food for swallowing is bolus.
- **Throat**: It, also called the pharynx is the next destination for food from where, food travels to the esophagus or swallowing tube.

A person cannot swallow and breath at a time, because pharynx is the common passage for food , water and air.

The opening of lungs i.e. trachea is protected by a cartilagenous structure called epiglottis.



- **Esophagus :** It is a muscular tube extending from the pharynx to the stomach. By means of a series of contractions and relaxations, called peristalsis, the esophagus delivers food to the stomach. Just before the connection to the stomach, there is a contractual structure called the lower esophageal sphincter this is a "valve" meant to keep food from passing backwards into the esophagus.
- **Stomach :** It is a sac-like organ with strong muscular walls. In addition to holding the food, the stomach secretes acids and

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enzymes that continue the process of breaking down and digesting food, *i.e.* causes both mechanical and chemical digestion of food. The stomach also helps in killing the harmful pathogens came along the food. When it leaves the stomach, food has the consistency of a liquid or paste called chyme, the form in which it enters into the small intestine.

- **Small Intestine :** It is a long tube loosely coiled in the abdomen. If spread out, then more than 20 feet long is made up of three segments, duodenum, jejunum and ileum. It continues the process of breaking down food by using enzymes released by the pancreas, intestinal glands secreting sacchus entericus (intestinal juices) and bile from the liver. Bile synthesized in liver but stored in gall bladder aids in the digestion of fat and eliminates waste products from the blood. The peristalsis propels the food slowly in the small intestine. mixing, it up with intestinal secretions (saccusentricus). The duodenum, U-shaped at the beggining of the small intestine is largely responsible for continuing the process of breaking down food coming from the stomach. The jejunum and the ileum are mainly responsible for the absorption of nutrients into the bloodstream to be first carried to the liver for assimilation by hepatic portal vein.
- **Colon (Large Intestine) :** It is 5- to 6-foot-long muscular tube that connects the caecum junction between the small and large intestines to the rectum (the last part of the large intestine). The waste left-over food from the digestive process is passed through the colon by means of peristalsis, first in a liquid state and ultimately in solid form as the water is absorbed from the stool. The stool so formed is stored in the rectum for elimination, *i.e.* egestion once or twice a day.

About 150 species of ruminants both domestic and wild such as cow, buffalo, deer, goat, giraffe, yak, etc. have four-chambered stomachs for storing, fermentation and digestion of food. These chambers are rumen, reticulum, omasum and abomasum. In the first two chambers, the rumen and the reticulum, the food is mixed with saliva and separates into layers of solid and liquid. material. Solids clump together to form the cud for rechewing it.

Food

↓

Mouth : Ingestion, mastication and digestion of starch by salivary amylase(Ptyalin) into maltose. Bicarbonate ions in saliva neutralise the food.

↓

Stomach : Churning and mechanical breaking down of food. Addition of HCl to prevent the putrefaction of food, creation of adequate acidic conditions for the action of pepsin on proteins and of rennin on milk proteins. The goblet cells present in the mucous epithelium secrete the mucus for lubrication and protection of epithelial surface from HCl.

↓

- **Duodenum :** Duodenum receives the digestive enzymes from the pancreass and bile from the liver (stored in galls bladder). Addition

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of bile juice to neutralize the incoming acidic chyme and emulsify fats and oils for their digestion. The neutral- ized chyme is called chyle. Pancreatic juice containing amylase , trypsin, lipase and nucleases causing the digestion of partially digested starch and other carbohydrates, trypsin the digestion of proteins, lipases of fats and oils and nucleases of the nucleic acids respectively.

- **Absorption :** Once the food is digested, *i.e.* carbohydrates into glucose, proteins into respective amino acids, fats into fatty acids and glycerol, the absorption takes place in the jejunum and ileum part of the small intestines. Fatty acids and glycerol are absorbed in lymph vessels called lacteals while the absorption of the rest takes place in blood. The hepatic portal vein carries the absorbed food from ileum to liver for assimilation.

↓

- **Colon :** It involves the absorption of water, hence, the formation of stool/faeces before their egestion through anus.

Although HCl and bile juice are not enzymes yet play a significant role in the process of food digestion.

- **Liver (structure and functions) :** The liver, the largest gland, in the body is located in the upper right quadrant of the abdominal cavity, beneath the diaphragm and on top of the stomach, right kidney, and intestines. The liver, a dark reddish-brown organ, has two main lobes, both of which are made up of 8 segments. The segments are further made up of a thousand lobules connected to small ducts that connect with larger ducts to ultimately form the common hepatic duct. The common hepatic duct transports bile produced by the liver cells to the gall bladder as cystic duct.
- **Blood supply to liver**: There are two distinct sources that supply blood to the liver :

  — Oxygenated blood flows in from the hepatic artery.

  — Nutrient rich deoxygenated blood flows in from the hepatic portal vein.

  Functions of the liver : The vital functions of the liver include :

  Metabolism of proteins, fats and carbohydrates.

  — Production of bile, which helps carry away waste and break down fats in the small intestine during digestion

  — Production of certain proteins for blood plasma, e.g. Prothrombin and fibrinogen, cholesterol and special proteins to help carry fats through the body along with being site for the production of vitamin - A from absorbed carotenes.

  — Store and release glucose as needed. The excessive glucose is stored as glycogen.

  — Processing of haemoglobin for the use of its iron-content (the liver stores iron along with any other minerals).

  — Conversion of harmful ammonia to urea, the end products of protein metabolism.

  — Metabolism of drugs and other harmful substances like alcohol etc.

  — Resisting infections by producing immune factors and removing bacteria from the bloodstream

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— Clearance of bilirubin (if there is excessive accumulation of bilirubin, the skin and eyes turn yellow).

— Storage of vitamins A,D, E, K B_{12} and minerals like iron and copper.

When the liver has broken down harmful substances, they are excreted into the bile or blood. Bile by-products enter the intestine and ultimately leave the body in the faeces. Blood by-products are filtered out by the kidneys and leave the body in the form of urine.

➢ **Bile :** Bile is secreted from liver via gall bladder into the duodenum part of small intestines. It is watery greenish fluid containing bile pigments, bile salts, cholestorol and phospholipids. Bile salt play important role in Metabolism of fats.

People with their gall bladders removed cannot digest lipids, i.e. fats and oils.

RESPIRATORY SYSTEM

The Pathway of air :

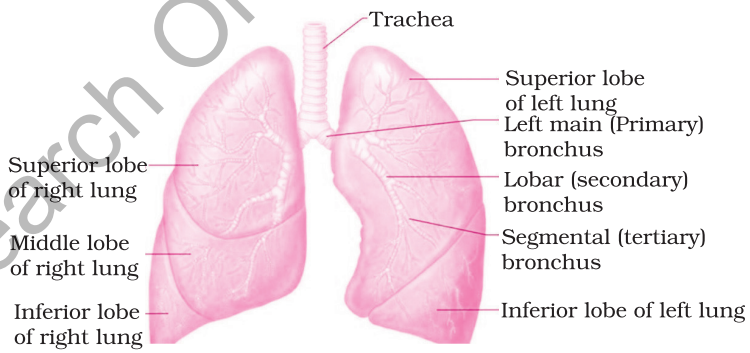
Nostrils→Nasopharynx→Oro pharynx → Laryngopharynx → Trachea → Bronchi→ Alveoli↔Respiratory bronchiole↔Bronchioles

➢ Only in the alveoli the actual gas exchange take place. There are some 300 million alveoli in two adult lungs. These provide a surface area of some 160 m^2 (almost equal to the area of a tennis court and 80 times the area of our skin).

Breathing In mammals, the diaphragm divides the body cavity into the

— abdominal cavity, which contains the viscera (e.g., stomach and intestines) and the

— thoracic cavity, which contains the heart and lungs.



Human Lungs

➢ There are a total of five lobes of lungs, three on the right side and two on the left side.

➢ The inner surface of the thoracic cavity is attached with outer surface of the lungs, lined with pleural membranes which adhere to one another. If air is introduced between them, the adhesion is

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broken and the natural elasticity of the lung causes it to collapse. This can occur due to trauma. And it is sometimes induced deliberately to allow the lung to rest. In either case, reinflation occurs as the air is gradually absorbed by the tissues. The fluid is secreted from the membranes help in lubrication.

Because of this adhesion, any action that increases the volume of the thoracic cavity causes the lungs to expand, drawing air into them. A single beathing involves inhalation followed by exhalation.

- **Inhalation**: During inspiration (inhalation), that normally lasts for two seconds
  - — The external intercostal muscles contract, lifting the ribs up and out.
  - — The diaphragm contracts, drawing it down .
- These two together enforce the chest cavity to expand with decreasing pressure inside.
- **Exhalation :** During expiration (exhaling), that normally lasts for three seconds, the above-stated processes are reversed and the natural elasticity of the lungs returns them to their normal volume. At rest, we breathe 15–18 times a minute exchanging about 500 ml of air, also called tidal volume of air. It is the volume of air normally inspired and expired with in a breath without efforts.
- In more vigorous expiration,
  - — the internal intercostal muscles draw the ribs down and inward
  - — the wall of the abdomen contracts pushing the stomach and liver upward.
- Under these conditions, an average adult male can flush his lungs with about 4 liters of air at each breath. This is called the vital capacity. It is the maximum amount of air a person can expel from the lungs after filling the lungs to their maximum extent. It depends on age, sex and height of an individual. Even with maximum expiration, about 1200 ml of residual air remains in the lungs.
- The extra volume of air that can be inspired beyond the tidal volume is known as Inspiratory reserve volume. It is about 2500-300 ml.
- The table shows what happens to the composition of air when it reaches the alveoli. Some of the oxygen dissolves in the film of moisture covering the epithelium of the alveoli. From here it diffuses into the blood in a nearby capillary. It enters a red blood cell and combines with the haemoglobin therein.
- At the same time, some of the carbon dioxide in the blood diffuses into the alveoli from which it can be exhaled.

Component	Inhaled air (%)	Exhaled air(%)
N_2 plus inert gases	78.62	74.9
Oxygen	20.85	15.3
Carbon dioxide	0.03	03.6
Water	0.05	06.2
	100%	100%

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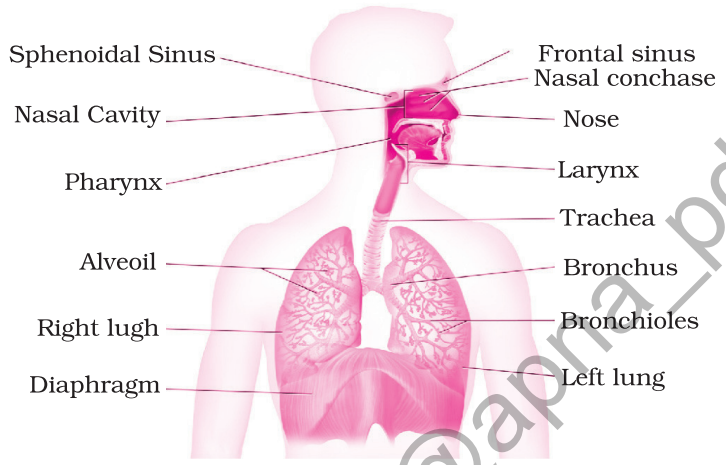
- The very fine thickness of the epithelial cells that line the alveoli and capillary allows for easy gaseous exchange. At the closest point, the surface of the red blood cell is only 0.7 μm away from the air in the alveolus.



Inhalation involves participation of 10 muscles while exhalation involves only 8 muscles, mostly abdominal.

- **Central Control of Breathing :** The rate of cellular respiration (and hence oxygen consumption and carbon dioxide production) varies with the level of respiratory activity. Vigorous exercise can increase by 20–25 times the demand of the tissues for oxygen. This is met by increasing the rate and depth of breathing.

  It is a rising concentration of carbon dioxide assessed in carotid artery first, not a declining concentration of oxygen that plays a major role in regulating the ventilation of the lungs. Certain cells in the medulla oblongata are very sensitive to a drop in pH. As the CO_2 content of the blood rises above normal levels, the pH drops and the medulla oblongata responds by increasing the number and rate of nerve impulses that control the action of the intercoastal muscles and diaphragm. This produces an increase in the rate of lung ventilation, which quickly brings the CO_2 concentration of the alveolar air, and then of the blood, back to normal levels.
- **Respiratory centres in brain:** There are three centres in medulla oblongata of brain where bundle of neurons present, that controls the rate of respiration.

  (1) The dorsal respiratory group

  (2) The ventral respiratory group

  (3) The pheumotaxic centre.
- **Modes of cellular respiration :** There are two possible modes of respiration, called aerobic respiration and anaerobic respiration. Normally up to a certain level of energy demand, aerobic respiration

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takes place producing carbon dioxide and water with the release of 36ATP molecules. Sometimes when energy demand increases beyond a certain level such as during the course of vigorouus exercise, anaerobic respiration producing only two ATPs too occurs simultaneously to meet the energy demand. However, the onset of anaerobic respiration leads to the accumulation of lactic acid in muscles cells that later cause the muscular cramps. These cramps last until the lactic acid has been oxidized or removed from the cells. Aerobic respiration :

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38ATP$$

Anaerobic respiration : $C_6H_{12}O_6 \longrightarrow 2\ C_3H_6O_3 + 2ATP$

- Muscular cramps last until lactic acid is removed from the muscles either by hepatic cells of liver or is oxidized later to yield CO_2 and water.

$$4/5\ \text{Lactic acid} + \text{Water} \xrightarrow{\text{ATP}} \text{Glycogen (Hepatic cells)}$$

$$1/5\ \text{Lactic acid} + O_2 \xrightarrow{\text{ATP}} CO_2 + H_2O + \text{ATP (Hepatic cells)}$$

$$ATP + H_2O \xrightarrow{\text{Creatine phosphokinase}} ADP + Pi + \text{Energy}$$

$$\text{Creatine} + ATP \longrightarrow \text{Creatine phosphate} + ADP\ \text{(Resting muscles)}$$

Transport of carbon dioxide from body cells to lungs for gaseous exchange takes place in three forms: 85% in the form of bicarbonates of sodium or potassium, 10% carbohaemoglobin and 5% as carbonic acid.

- **Carbon monoxide poisoning** : With haemoglobin being 250 more sensitive to CO than oxygen, its poisoning occurs after too much inhalation of carbon monoxide (CO). It is a toxic gas, but, being colourless, odourless, tasteless, and initially non-irritating, it is very difficult for people to detect. Carbon monoxide is a product of incomplete combustion of organic matter due to insufficient oxygen supply to enable complete oxidation to carbon dioxide (CO_2). It is often produced in domestic or industrial settings by motor vehicles that run on gasoline, diesel, methane or other carbon-based fuels and from tools, gas heaters and cooking equipment that are powered by carbon-based fuels such as propane, butane and charcoal. Exposure at 100 ppm or greater can be dangerous to human health leading to oxygen starvation of body cells that can be fatal.
- Symptoms of mild acute poisoning include, confusion, headache and flu-like effects, larger exposures can lead to significant toxicity of the central nervous system and heart, and death.
- Carbon monoxide mainly causes adverse effects by combining with haemoglobin to form carboxyhaemoglobin (HbCO) in the blood. This prevents haemoglobin from carrying oxygen to the tissues, effectively reducing the oxygen-carrying capacity of the blood, leading to hypoxia. Carboxyhaemoglobin can revert to haemoglobin, but the recovery takes time the HbCO complex being fairly stable.

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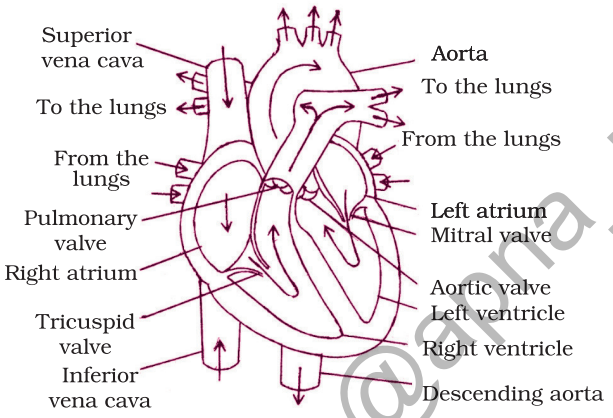
Treatment of poisoning largely consists of administering 100% oxygen or providing hyperbaric oxygen therapy.

CARDIOVASCULAR SYSTEM

- The cardiovascular system is comprised of blood, types of blood vessels and heart, as a pumping organ.



Human Heart

- **Blood:** It is fluid connective tissue composed of formed components, *i.e.* cells, and an aqueous solution (plasma). The blood cells, erythrocytes, leucocytes, thrombocytes, can be separated from plasma by centrifugation.
- It makes up about 8% of the human body-weight. The volume percentage of all blood cells in the whole blood of an adult is about 45%. The rest consists of liquid plasma (e.g. water, plasma proteins, electrolytes, etc.).
- **Red blood cells :** RBCs, also known as erythrocytes, have two main functions:
  1. To pick up oxygen from the lungs and deliver it to tissues all over the body.
  2. To pick up carbon dioxide from other tissues and unload it in the lungs.

  The biconcave shape of an RBC has a greater ratio of surface area to volume, enabling O_2 and CO_2 to diffuse quickly to and from haemoglobin.
- The plasma membrane of a mature RBC has glycoproteins and glycolipids that determine a person's blood type. On its inner surface are two proteins called spectrin and actin. They give the membrane resilience and durability to allow the RBCs to stretch, bend and fold as they squeeze through small blood vessels, and to spring back to their original shape as they pass through larger vessels.

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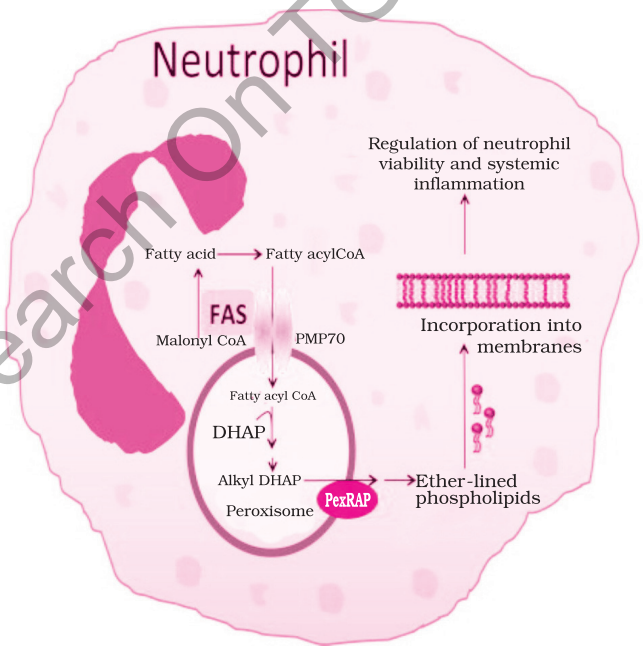
- The cytoplasm of an RBC consists mainly of a 33% solution of haemoglobin (Hb), which gives RBCs their red colour. Haemoglobin carries most of the oxygen and some of the carbon dioxide transported by the blood.
- Circulating erythrocytes having ratio of about 1000:1 with WBCs. Their lifespan is about 120 days being without nucleus and other vital cell organelles. Many RBCs die in the spleen (Graveyard of RBCs) and liver where they become trapped in narrow channels, broken up and destroyed.

  Among humans during embryonic and foetal stage the development of RBCs takes place in liver but after birth, their development occurs in bone marrow while the liver becomes the site of their destruction along with the spleen.
- **White blood cells :** WBCs are also known as leucocytes. They can be divided into granulocytes and agranulocytes. The former have cytoplasms that contain organelles that appear as coloured granules. Granulocytes based on the type of stain used for staining them and their consitutents are of three types; neutrophils, eosinophils and basophils. In contrast, agranulocytes do not contain granules. They consist of lymphocytes and monocytes.
- **Neutrophils :** These contain very fine cytoplasmic granules that can be seen under a light microscope. These are also called polymorphonuclear (PMN) because they have a variety of nuclear shapes. They play roles in the destruction of bacteria and the release of chemicals that kill or inhibit the growth of bacteria.



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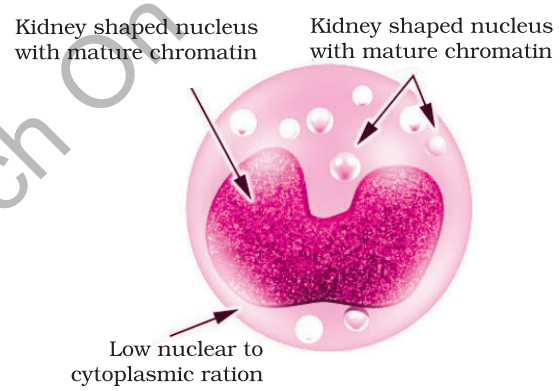
- **Eosinophils :** These have large granules and a prominent nucleus that is divided into two lobes. They function in the destruction of allergens and inflammatory chemicals, and release enzymes that disable parasites, detoxification, They are less than 3 percent in number.
- **Basophils :** They have a pale nucleus that is usually hidden by granules. They secrete histamine which increases tissue blood flow via dilating the blood vessels, and also secrete heparin which is an anticoagulant that promotes the mobility of other WBCs by preventing clotting.
- **Lymphocytes :** These are usually classified as small, medium or large. Medium and large lymphocytes are generally seen mainly in fibrous connective tissue and only occasionally in the circulating bloodstream. Lymphocytes function in destroying cancer cells, cells infected by viruses, and foreign invading cells. In addition, they present antigens to activate other cells of the immune system. They also coordinate the actions of other immune cells, secrete antibodies and serve in immune memory. However, based on the site of their maturity, they are of two types: T-lymphocytes and B-lymphocytes. The former mature in thymus gland while the latter in bone marrow, the site of their development.
- **Monocytes :** They are the largest of among all the Leukocytes. They have kidney shaped nucleus. They function in differentiating into macrophages, which are large phagocytic cells, and digest pathogens, dead neutrophils and the debris of dead cells. Like lymphocytes, they also present antigens to activate other immune cells.



Monocyte

- **Blood Platelets :** These also called thrombocytes are small fragments of bone marrow cells and are, therefore, not really classified as cells themselves. They have the following functions:
  — Secrete vasoconstrictors which constrict blood vessels, causing vascular spasms in broken blood vessels
  — Form temporary platelet plugs to stop bleeding

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— Secrete procoagulants (clotting factors) to promote blood clotting
— Dissolve blood clots when they are no longer needed.

- **Mechanism of blood coagulation :** The whole mechanism can be summarized as :

  Damaged vessel activates
  Thrombocytes to secrete thromboplastin
  ↓
  Prothrombin → Thrombin
  Ca+ Vit.-K
  Fibrinogen → Insoluble fibrin (clot)

- The importance of blood coagulation lies in the fact that it prevents not only excessive blood loss by plugging the cut point but also the direct entry of pathogens into body.
- **Blood groups:** Humans after the discovery of blood groups by Karl Landstainer in 1900 have known to posses four major blood groups determined by the presence or absence of two antigens – A and B on the surface of red blood cells.

Group A:	has only the A antigen on red cells (and B antibody in the plasma)
Group B :	has only the B antigen on red cells (and A antibody in the plasma)
Group AB :	has both A and B antigens on red cells (but neither A nor B antibody in the plasma)
Group O :	has neither A nor B antigens on red cells (but both A and B antibodies are in the plasma)

Blood Groups and Campatibility

Blood Group	Autigen on RBCs	Antibodies in Plasma	Donor's Group
A	A	Anti-B	A,O
B	B	Anti-A	B,O
AB	A,B	—	AB, A,B,O
O	—	Anti-A,B	O

There are very specific ways in which blood types must be matched for a safe transfusion.

- In addition to the A and B antigens, there is a third antigen called the Rh factor, which can be either present (+) or absent (–). In general, Rh negative blood is given to Rh-negative patients, and Rh positive blood is given to a Rh-positive patients. However, Rh negative blood may be given to a Rh-positive patient.

  The universal donor is Type O negative blood type.
  The universal recipient is Type AB blood type.

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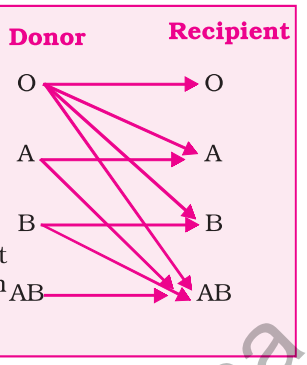
In case of emergency, serum is transfused to restore blood volume.
Serum = Blood plasma – Plasma proteins

Blood group O can donate to all beings (universal donor).
Blood group A can donate to A and AB.
Blood group B can donate to Ba and AB.
Blood group AB can donate to AB only, but can receive blood from all others.
(universal recipient)



- **Rh blood group system :** It is based on the presence or absence of the Rh antigen, often called the Rh factor, on the cell membranes of RBCs. Karl Landsteiner and A.S. Weine in 1940 discovered this as an antigen in human blood group after its presence in a rhesus monkey. The Rh antigen poses a danger for the Rh-negative person, who lacks the antigen, if Rh-positive blood is given in transfusion. Adverse effects may not occur the first time Rh-incompatible blood is given, but the immune system responds to the foreign Rh antigen by producing anti-Rh antibodies. If Rh-positive blood is given again after the antibodies have been formed, destruction of RBCs causes serious illness and sometimes death.

  When the mother is Rh-negative and the father is Rh-positive, the first child is usually in no danger. However , during labour a small amount of the foetus's blood may enter the mother's bloodstream. The mother then produces anti-Rh antibodies, which attack any Rh-incompatible foetus in subsequent pregnancies. This process produces erythroblastosis foetalis, or haemolytic disease of the newborn, fatal to the foetus or to the infant shortly after birth.

- **Blood vessels and their types :** There are five types of blood vessels:
  - Arteries, thick muscular walled endotheliums, carry blood away from the heart, under pressure. The main artery is the aorta.
  - Smaller arteries called arterioles diverge into capillary beds, which contain 10-100 capillaries that branch among the cells and tissues of the body.
  - Capillaries carry blood away from the body and exchange nutrients, waste and oxygen with tissues at the cellular level.
  - Veins are blood vessels with valves that bring blood back to the heart and drain blood from organs and limbs.

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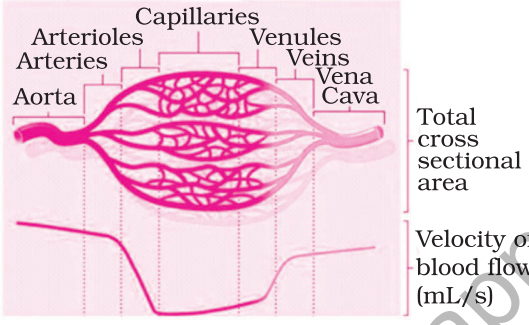
— Capillaries have one layer of cells (the endothelial tunic or tunica intima) where diffusion and exchange of materials takes place.

— Veins and arteries have two more tunics that surround the endothelium: the middle tunica media is composed of smooth muscle that regulates blood flow, while the outer tunica externa is connective tissue that supports blood vessels.



Pulmonary artery and pulmonary vein differ from each others as the pulmonary artery carries deoxygenated blood unlike the other arteries away from the heart while the pulmonary vein brings the oxygenated blood from lungs to the heart.

- **Types of circulatory system :** There are two types of circulatory system :
- **Single Circulatory System**: It is a simple loop in which blood flows: Heart > Gills > Body > Heart
- **Double Circulatory System :** It is a double loop in which blood flows :

  Heart → Lungs → Heart → Body → Heart
- A fish has a single circulatory system, while mammals and birds have double circulatory systems.
- In a double circulatory system, the blood flow between the heart and lungs is called the pulmonary circulation while the blood flow between the heart and body is called the systemic circulation.
- The double circulatory system is meant to prevent the intermixing of the oxygenated and deoxygenated blood to meet the oxygen demand in organisms that require more energy like birds and mammals.
- **Heart, structure and function :** The heart, a roughly triangular shaped organ like a closed fist is located under the rib cage, to the left of breastbone (sternum) and between the lungs. Internally, it is a four-chambered structure with upper atriums and lower ventricles. The right and left sides of the heart work together.

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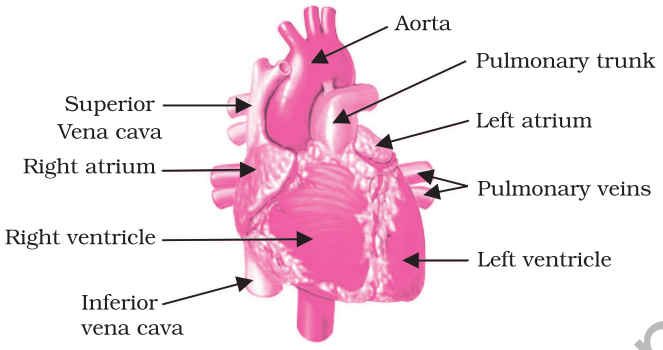

- **Atrial relaxation (diastole) :** In the right atrium blood enters the heart through two large veins, the inferior and superior vena cava, emptying deoxygenated blood from the body into the right atrium while in the left atrium the pulmonary vein empties oxygenated blood, from the lungs into the left atrium.
- **Cardiac cycle :** The sequence of events that occur from the beginning of one heartbeat to the next one is called as one cardiac cycle.

  The phase of one contraction is called systole and the phase of relation is a diastole. One systole and diastole of both the atria and that of both the ventricles becomes one heart beat. The normal heart beat rate is 72-80 per minute *i.e.* 0.85 heart beat persecond.
- **Atrial contraction (systole) :** The blood flows from the right atrium into the right ventricle and the left atrium into the left ventricle through the openings of tricuspid and bicuspid valve respectively. When the ventricles are full, the valves shut to prevent any back flow of blood.
- **Ventricular contraction (Systole) :** From the right ventricle blood leaves the heart through the pulmonary valve, into the pulmonary artery and to the lungs while from the left ventricle blood leaves the heart through the aortic valve, into the aorta and to the body. This pattern is repeated, causing blood to flow continuously to the heart, lungs and body.
- **Heart sounds :** During a single beat of duration 0.8 sec in *which* systole lasts for 0.27 sec *and* diastole 0.53 sec, the heart produces two "lubb-dubb"sounds. These sounds can easily be heard using a stethoscope. The closing of the mitral and tricuspid valves (known together as the atrioventricular valves) at the beginning of ventricular systole causes the first part (the lubb) and the second part (the dubb) of the "lubb-dubb". These two heart sounds caused by the closure of the aortic and pulmonary valves at the end of ventricular systole.

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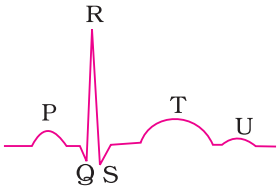
A human heart is myogenic with impulse for contraction generating at S.A. (Sino arterial) node, also called pace maker.

- **Electrocardiogram (ECG) :** It is one of the most convenient and Inexpensive ways to study the heart functioning. P wave is the first short upward movement of the ECG tracing. It indicates that the atria are contracting, pumping blood into the ventricles.



- The QRS complex normally begins with a downward deflection, The PR interval indicates the transit time for the electrical signal to travel from the sinus node to the ventricles. T wave is normally a modest upward waveform representing ventricular repolarization.
- **Blood pressure :** The lateral pressure exerted by the blood on the walls of the blood vessels especially the arteries is known as blood pressure. Blood pressure is typically recorded as two numbers, written as a ratio of systolic pressure to diastolic pressure. It rises with each heartbeat and falls when heart relaxes between beats. BP can change from minute to minute with changes in posture, exercise, stress or sleep. Normally, BP should be 120/80 mm Hg, i.e. 120 systolic and 80 diastolic for an adult aged 20 or above. It is measured using the instrument called sphygmomanometer.
- **CAD and heart :** CAD refers to coronary artery disease, the principal cause of heart attack or failure leading to death. The three principal causes so far identified for CAD include thrombosis, *i.e.* blood coagulation, arteriosclerosis the hardening of coronary arteries which supplies to heart muscles for contraction and atherosclerosis, *i.e.* deposition of fats or cholesterol in blood vessels obstructing blood flow.

EXCRETORY SYSTEM

- **Excretion :** It refers to the elimination/removal of metabolic wastes from the body.
- **Organs of excretion :** The four major organs of excretion are the kidneys, the lungs, the skin, the liver. The kidneys are the primary excretory organs that eliminate metabolic waste products in the form of urine. The main components of urine are surplus water and nitrogenous waste urea and uric acid produced from the breakdown of proteins in liver (deamination).

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- The principal function of the liver is to produce bile, through which it excretes cholesterol, drugs electrolytic balance and steroid hormones. The liver also purifies any toxic substance that may enter the body through the alimentary canal.
- The lungs help to remove water vapour and carbon dioxide by means of exhalation and diffusion.
- The skin's sweat glands excrete sweat during perspiration. Foreign elements are also excreted in the form of hair and nails.
- Salivary glands play an important role in the elimination of heavy metals along with water and other wastes.
- The primary function of the renal system is to regulate blood volume and plasma osmolarity, electrolytic balance and waste removal via urine is essentially a convenient way in which the body performs many functions using one process.
- **Structure of kidneys :** A kidney is a bean-shaped organ present on each side of the posterior portion of the abdominal cavity. The larger left kidney is located a bit higher than the right kidney. Each kidney having a million of its functional unit called nephron has an outer convex side and an inner concave side called the renal hilus, where the renal artery, vein, and ureter are found.
- **Renal artery :** It brings the unfiltered blood to the kidney for filtration.
- **Renal vein :** It carries the filtered blood back to the body.
- **Ureter :** It is tube that carries the urine from kidney to the urinary bladder for temporary storage until its final elimination from the body.
- The temporary storage of urine and its final expulsion from the urinary bladder is called micturition.

Functions of a kidney :

— Excretion of wastes and toxins such as urea, uric acid, ammonia and excess salts.

— Maintenance of water balance and electrolyte balance in the body.

— Regulation of blood pressure by producing angiotensin, a substance that constricts blood vessels and signals the body to retain water and sodium when blood pressure is low.

— Regulation acid-base balance to keep the blood pH 7.2 -7.4 and body healthy.

— Regulation of RBC development in bone marrow with the secretion of hormone erythropoietin,

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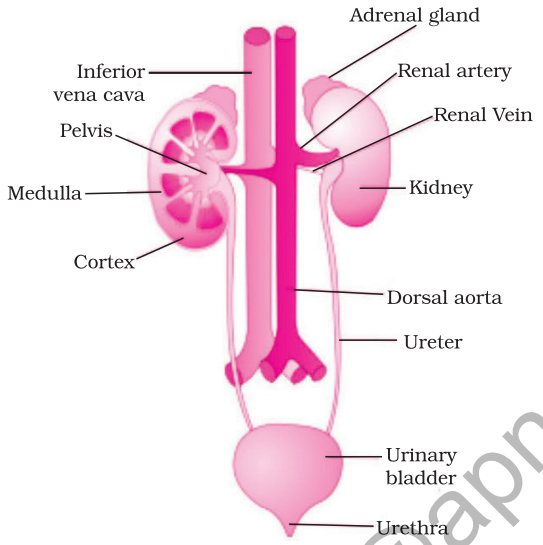

Kidneys receive blood at rate of 1.2 litres/min in an adult i.e. a quarter of the total output of the heart (5 litres/min) but produce only 1.5 litres of urine in a normal healthy person under ideal conditions. Urine contains 95% water, 2% urea, 2.8% of dissolved salts and ions and 0.2% ammonia, uric acid and creatinine.

- **Urine and its formation :** Urine is a waste by-product formed from excess water and metabolic waste molecules during the process of renal system filtration. Urine formation involves three processes: ultrafiltration, reabsorption and secretion.
- **Ultra filtration :** Blood enters the afferent arteriole and flows into the glomerulus where blood undergoes ultrafiltration with water and nitrogenous waste pass as filtrate inside as glomerular filtrate in Bowman's capsule, and non-filterable components such as cells and serum albumins exit via the efferent arteriole. About 20% of the total blood pumped by the heart each minute enters the kidneys to undergo filtration.
  The above is done with two intrinisc mechanisms:
  (1) Myogenic mechanism
  (2) Juxtaglomerular apparatus (JGA)
  — The glomerular filtration rate (GFR) is about 125 ml per minute.
- **Reabsorption :** It involves the reabsorption of molecules and ions back into the circulatory system from the glomerular filtrate as it passes through the components of the nephron tubules (the proximal, distal convoluted tubules, loop of henle, collecting duct) to maintain osmolarity.
- **Secretion :** Some substances with high molecular mass such as creatinine and drugs are removed from blood through their secretion into glomerular filtrate by the investing capillaries network. The

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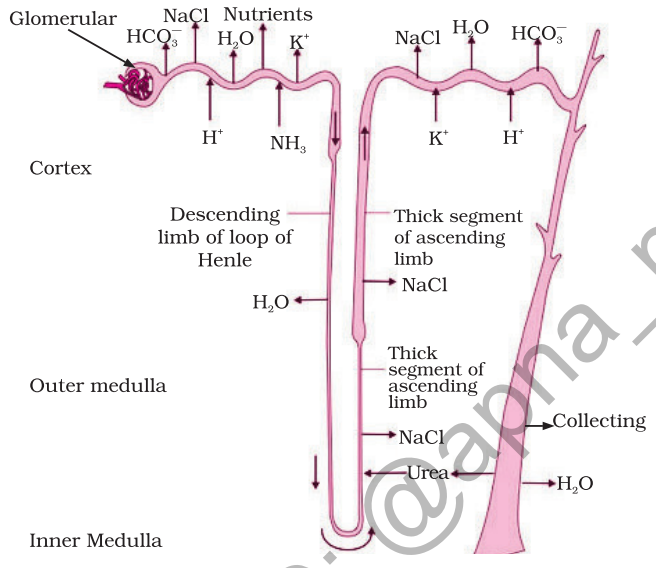
end-product of all these processes is urine, which is essentially a collection of substances that has not been reabsorbed during glomerular filtration or tubular reabsorbtion.



Filtration, Reabsorption, Seoretion in Nephrone

- **Haemodialysis :** It is a treatment facility available to patients suffering from kidney failure while waiting for kidney transplant. In severe conditions it needs to be performed 3 times a week, with each session lasting about 4 hours, depending on the body size and medical condition. During dialysis, two needles are inserted into the radial veins, one to remove the blood and the other to return the cleansed blood to the body. The patient is connected (via tubing) to the dialysis machine through a vein in the arm; the blood is pumped from the body to a special filter called the dialyser, which is made of tiny capillaries. In a dialyser, waste products and excess water are removed before the purified blood is returned to the patient's body through larger tubes.

SKELETAL SYSTEM

- **Human skeleton :** It is the internal framework of the body composed of 270 bones at birth that reduces to 206 bones by adulthood after some bones have fused together by process called ossification. The bone mass in the skeleton reaches maximum density around the age of 30 years.
- **Division of human skeleton :** The human skeleton has been divided into the axial skeleton and the appendicular skeleton.
- The axial skeleton having 80 bones is formed by the vertebral column (32–34 bones); the number of the vertebrae differs from human to human as the lower 2 parts, sacral and coccygeal bone,

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may vary in length, a part of the rib cage with 12 pairs of ribs and the sternum, and the skull having 22 bones and 7 associated bones including 'U' shaped hyoid bone that supports the tongue.

- **Vertebrae and movement :** While standing erect, the centre of the gravity of a body lies between heels but it shifts while bending forward or backward.
- **Forward movement :** Cervical and lumbar vertebrae
- **Backward movement :** Thoracic and sacral vertebrae
- **Movement of head :** Atlas , the first vertebra and axis, the last 7th cervical vertebra.
- The appendicular skeleton, which is attached to the axial skeleton having 126 bones, is formed by the pectoral girdles, the upper limbs, the pelvic girdle or pelvis, and the lower limbs. Each of the forelimb and the hind limb has 30 bones.Their functions are to make locomotion possible and to protect the major organs of digestion, excretion and reproduction.

  Humerus is the lognest bone in the forelimb.

Femur, the thigh bone is the longest, heaviest and strongest bone of body. The hardest bone in the human body is the mandible, which is more commonly known as the jawbone. It helps to speak. This bone is also the largest and strongest bone in the human face. The smallest bone in the human body is the stapes (stirrup), and it is located in the middle ear.

Distribution of bones in human body

There are axial and appendicular bones.

(The appendages are the arms and legs, which contain approximately 30 bones each.)

There are typically 22 bones in the head.

There are 33 bones in the spine.

These include :

7 Cervical (Cervix neck)

12 Thoracic (thorax)

5 lumbar

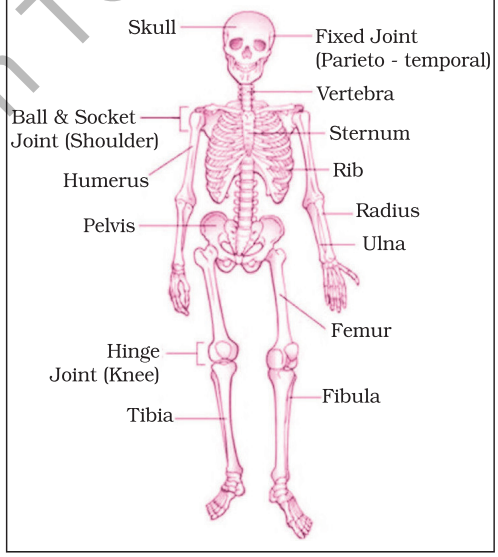
5 sacral

4 coccyx.

The pelvic girdle is fused to the sacrum at the sacro-illiac joint.

The pelvis is the part that is added onto the spine.

Human Skeleton



The thorax (chest) consists of 12 pairs of ribs; that attached to the respective thoracic vertebrae.

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first 7 pairs 'true' ribs - joined directly to the sternum (breast-bone), next 3 pairs 'false' ribs - joined to the sternum by cartilage, attached to each other. They are called as vertebrochondral ribs attached to each other. They are called as vertebrochondral ribs. The last 2 pairs 'floating' ribs are not connected to the sternum.

The shoulder girdle consists of the scapula (shoulder blade) and the clavicle (collar bone

- **Functions of skeletal system :** The human skeleton performs six major functions; support, movement, (locomotion) protection, production of blood cells, storage of minerals and endocrine regulation.
- **Types of joints :** Joints are strong connections that join the bones, teeth and cartilages of the body to one another. Each joint is specialized in its shape and structural components to control the range of motion between the parts that it connects. Basically, a joint in a body can be synovial joint or non-synovial permanent joint.
- **Synovial joints :** These joints permit the movement of bones, hence, they have synovial membrane secreting synovial fluid as lubricant. These joints are :
- **Gliding joints :** The ones between the carpals of the wrist, are those where bones meet as flat surfaces and allow for the bones to glide past one another in any direction.
- **Hinge joints :** Those at the elbow and knee, limit movement in only one direction so that the angle between bones may increase or decrease at the joint. The limited motion at hinge joints provides for more strength and reinforcement from the bones, muscles, and ligaments that make up the joint.
- **Saddle joints :** These joints such as the ones between the first metacarpal and trapezium bone, permit 360 degrees motion by allowing the bones to pivot along two axes.
- **Pivot joints :** These joints allow the rotation of one bone around another such as atlas and axis bones present at the top of neck which permit movement in 180°.
- **Ball and socket joints :** The shoulder and hip joints form the ball and socket joints in the body. These joints have the freest range of motion of any joint in the body. They are the only joints that can move in a full circle and rotate around their axes. However, the drawback to the ball and socket joint is that its free range of motion makes it more susceptible to dislocation than less mobile joints as well as the fracture at the neck of the long bones.
- **Non-synovial joints :** These are permanent fixed joints which do not permit any kind of motion such as found in the facial bones of the skull.

Diseases of skeletal system

- **Arthritis :** It is a disorder of the joints that involves the inflammation of one or more joints. making movement difficult and painful. It is an ageing disease caused because cartilage in the affected joints degrades, softens and wears away. The most common form of arthritis is osteoarthritis, which affects both the larger and smaller joints of the human skeleton. The others are rheumatiod arthritis and gout.

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- **Osteoporosis :** It is a disease of bone where there is reduced bone mineral density, increasing the likelihood of fractures. It is most common in women after menopause, when it is called "postmenopausal osteoporosis", but may develop in men and premenopausal women in the presence of particular hormonal disorders and other chronic diseases or because of smoking and medications, specifically glucocorticoids ad due to old age. It usually has no symptoms until a fracture occurs. The patients are advised to go on calcium supplements along with vitamin D to avoid it.
- **Gout :** It is responsible for joint pains caused because of the accumulation of uric acid in synovial joints.
- **Strain v/s Sprain :** Strain refers to the twisting of tendons between bones and muscles while sprain refers to the twisting, stretching or tearing of ligament.
- **Prolapsed disc :** It refers to the displacement of (vertebral) discs from its normal position.

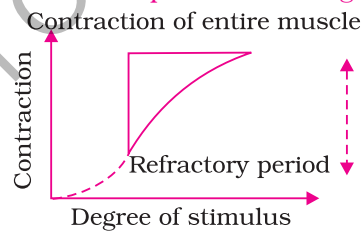
MUSCULAR SYSTEM

- In a human there are 639 muscles of varied sizes which contribute to 40% of total body-weight while 50% of the soft body-part.
- **Characteristics of muscles :** All muscles are mesodermal in origin characterized by:

  — 1/3 to 1/2 of contractibility of their original size. Contraction of entire muscle; on average, the value of muscular contraction is 100W/kg.

  — excitability, *i.e.* to get excited for contraction after the reception of a stimulus.

  Refractory period conductivity that involves the conduction of stimulus across the muscle after its reception. However, threshold is refractory period, *i.e.* a period of interval for responding to the two successive stimuli irrespective of the degree of stimulus.



- **Myofibrils and sarcomeres :** Most of the muscle fibre structure is made up of myofibrils, which are the contractile structures of the cell. Myofibrils are made up of many protein fibres arranged into repeating subunits called sarcomeres. **The sarcomere is the functional unit of muscle fibres.**
- **Sarcomere Structure :** Sarcomeres are made of two types of protein fibres : thick filaments and thin filaments.
- **Thick filaments :** Thick filaments are present in middle and are made of many bonded units of the protein myosin. Myosin is the protein that causes muscles to contract.

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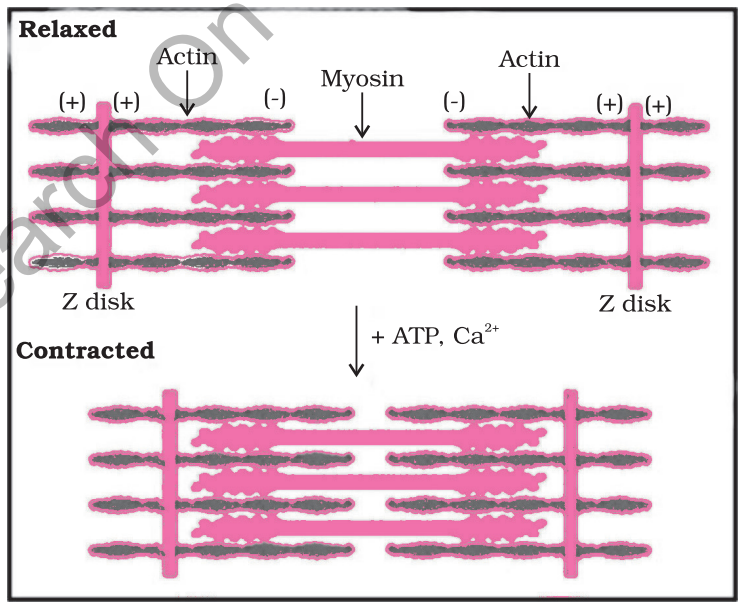
- **Thin filaments :** Thin filaments are present at the two ends, are made of three proteins:
  - **Actin :** Actin forms a helical structure that makes up the bulk of the thin filament mass. Actin contains myosin-binding sites that allow myosin to connect to and move actin during muscle contraction.
  - **Tropomyosin :** Tropomyosin is a long protein fibre that wraps around actin and covers the myosin binding sites on actin.
  - **Troponin :** Bound very tightly to tropomyosin, troponin moves tropomyosin away from myosin (–) binding sites during muscle contraction.
- **Muscular Contraction or Contraction Cycle :** Muscles contract when stimulated by signals from their motor neurons at Neuromuscular Junction (NMJ). The release of neurotransmitter like acetylcholine at the NMJ is bonded to the motor end plate containing many ion channels that open in response to neurotransmitters and allow Na^+ ions to enter the muscle fibre. The positive ions form an electrochemical gradient to form the inside of the cell.When the positive ions reach the sarcoplasmic reticulum, Ca^{2+} ions are released and allowed to flow into the myofibrils. Ca^{2+} ions bind to troponin, which causes the troponin molecule to change shape and move to the nearby molecules of tropomyosin. Tropomyosin is moved away from myosin-binding sites on actin molecules, allowing actin and myosin to bind together. ATP molecules power myosin proteins in the thick filaments to bend and pull on actin molecules in the thin filaments. Myosin proteins act like oars on a boat, pulling the thin filaments closer to the centre of a sarcomere.



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- As the thin filaments are pulled together, the sarcomere shortens and contracts. Myofibrils of muscle fibres are made of many sarcomeres in a row, so that when all of the sarcomeres contract, the muscle cells may shorten with a great force relative to its size.
- Muscles continue to contract as long as they are stimulated by a neurotransmitter. When a motor neuron stops the release of the neurotransmitter, the process of contraction reverses itself. enforcing the fibre to relax.
- **Red muscles v/s white muscles :** Red muscles are thin, narrow and red in colour with myoglobin. These muscles store oxygen and perform only aerobic respiration, hence, do not experience any muscular cramps. White muscles are broad, thick and pale in colour. These muscles on prolonged working experience the accumulation of lactic acid with the onset of anaerobic respiration along with aerobic respirations hence, undergo the state of developing muscular cramps.
- **Types of muscles with respect to function:** The muscles based on the type of movement they permit have been classified into different types such as :
- **Flexor:** Bending of one body part close to another such as triceps movement brings hand close to mouth.
- **Extensor :** Straightening of a body part, e.g., biceps
- **Adductor :** Brings the limbs towards the axis of body, e.g., latissimus dorsi
- **Abductor :** Takes the limbs away from the axis of body, e.g., deltoid
- **Pronator :** Rotates forearm to turn the palm upward.
- **Supinator:** Rotates forearm to turn the palm downward.
- **Depressor:** Lowers a body-part like lower mandible to open mouth.
- **Elevator:** Raises a body-part like lower mandible to close mouth.
- **Sphincter:** Closes an opening like cardiac and pyloric sphincter in stomach.

ENDOCRINE SYSTEM

- The endocrine system is the collection of glands which produce hormones that regulate metabolism, growth and development, tissue function, sexual function, reproduction, sleep, and mood, among other things.
- **Types of glands in a body :** All the glands present in a body have been classified into two types, exocrine and endocrine glands. The exocrine glands or having ducts or located closer to target pour their secretion, *i.e.* electrolytes or enzymes at the site of target via duct. Endocrine glands. These glands allow the hormones they produce to diffuse into blood to be carried to the target site.

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- The endocrine glands include hypothalamus, pituitary gland, thyroid gland, parathyroid glands, adrenal glands, pancreas, ovaries (in females) and testicles (in males). These glands together make up the endocrine system.
- The exocrine glands include salivary glands , sweat glands, sebaceous glands, liver, mammary glands, etc.
- Pancreas with Islets of Langerhans is considered as a heterocrine gland because of its ability to secrete both enzymes and hormones.

Different endocrine glands with their hormonal secretions and functions

Endocrine gland	Secretion	Function
Hypothalamus	Thyrotropin-releasing hormone (TRH), Corticotropin-releasing hormone, Growth hormone releasing hormone (GHRH), Gonadotropin-releasing hormone (GnRH) Dopamine	Stimulates the secretion of TSH and prolactin; ACTH Triggers the release of growth hormone, triggers the release of LH and FSH. Inhibits prolactin secretion.
Pituitary gland (Anterior lobe)	Adrenocorticotropic hormone (ACTH) Follicle-stimulating hormone (FSH) Growth hormone Thyroid-stimulating hormone (TSH) Luteinizing hormone (LH) Prolactin	Stimulates the synthesis and secretion of adrenocortical hormones (cortisol, androgens and aldosterone). Secretion of sex hormones from gonads, stimulate production of gametes Stimulates the synthesis of proteins and growth of cells and tissues. Stimulates the synthesis and secretion of thyroid hormones. In women, it stimulates ovulation, formation of the corpus luteum and production of estrogen and progesterone. In men, it stimulates the testes to produce testosterone. Promotes the development of breasts in women and milk production and secretion.
Pituitary gland (Posterior lobe)	Antidiuretic hormone (ADH) / Vasopressin Oxytocin	Stimulates the reabsorption of water from urine in the kidneys hence, osmoregulation and regulating blood pressure. Stimulates the secretion of milk from the breasts. It also triggers and enhances the uterine contractions, hence called birth hormone.

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Pituitary (Intermediatry lobe)	Melanocyte Stimulating Hormone (MSH)	Skin pigmentation
Thyroid	Thyroxine (T4) and Triiodothyronine (T3) Calcitonin	Regulate the body's metabolic rate. It also promotes calcium deposition in the bones. and also reduces the calcium levels present in the blood and tissue fluid. To regulate the development of mental faculties.
Parathyroid	Parathyroid hormone (PTH)	Regulate the calcium and phosphate balance in blood and other tissues. Dietary and reabsorption from kidney
Adrenal cortex	Cortisol Aldosterone	Regulates wide range of metabolic and anti- inflammatory effects. Gluco-corticoids, carbohydrate protein and lipid metabolism A mineralocorticoid regulates the concentration of essential electrolytes in the body. Glucocorticoids regulate carbo-hydrate, protein and lipid metabolism.
Adrenal medulla	Adrenaline and nor-adrenaline	Adrenaline prepares the body for any state of stress, hence, called emergency hormone also called 3-F hormone. Nor- adrenaline helps bring the body back to normal after adrenaline action such as reducing increased blood pressure , heart beat and breathing rate. etc.
Pancreas (Islets of Langerhans)	Insulin (β–cells) Glucagon (α–cells)	Regulates blood glucose level. Promotes the release of stored glucose from the liver and production of glucose.
Testes	Testosterone	Promotes the development and maturation of the testes, as well as the sexual charac-teristics of men.

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Ovaries	Estrogen	Promotes tissue development in the female reproductive system, including the ovaries, fallopian tubes, uterus and genitalia. Increases the growth and development of the breasts, as well as the sexual characteristics of women.
	Progesterone	Promotes secretory changes in the uterus and fallopian tubes in the preparation of pregnancy, hence, called pregnancy hormone. Stimulates the development of milk-producing tissue in the breast but does not stimulate actual breast milk secretion.

Some other body organs that are not part of the endocrine system also secrete hormones such as

Heart : Atrial natriuretic peptide (ANP)

Kidney- Renin, 1,2, 5-Dihydroxycholecalciferol and Erythropoietin

Placenta- Human chorionic gonadotropin (HCG) , relaxin and Progesterone

Stomach- Gastrin

Small intestine- Secretin and Cholecystokinin (CCK)

List of diseases caused by over or under secretion of hormones from different endocrine galnds :

- **Acromegaly :** It's a metabolic disorder characterized by the enlargement of the skeletal extremities. It is the result of the over-production of pituitary growth hormone (somatotropin) after maturity.
- **Addison disease :** It is the disorder caused by the destruction of adrenal corte. It is a rare disease as occurs only when at least 90 per cent of the adrenal cortex is destroyed. It results in imbalance in electrolytes concentration.
- **Breast cancer :** It's a disease characterized by the growth of malignant cells in the mammary glands. Breast cancer can strike males and females, although women are about 100 times more prone to develop the disease than men.
- **Cushing syndrome :** It's adisorder caused by the overactivity of the adrenal cortex *i.e.* excessive production of cortisol. If caused by a tumour of the pituitary gland, it is called Cushing disease. In 1932, American neurosurgeon Harvey Cushing described the clinical findings that provided the link between specific physical effects. It is also called as hypercortisolism.

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- **Diabetes insipidus :** It is a pathological endocrine condition characterized by excessive thirst and excessive production of very dilute urine. The disorder is caused by a lack of antidiuretic hormone (vasopressin).
- **Diabetes mellitus :** It's a disorder of carbohydrate metabolism characterized by the impaired ability of the body to produce insulin and thereby maintain the proper levels of sugar (glucose) in the blood. Diabetes is a major cause of morbidity and mortality,
- **Gigantism :** It is an excessive growth in stature, well beyond the average for the individual's heredity and environmental conditions. Gigantism is caused by the excessive secretion of growth hormones.
- **Goitre :** It stands for the enlargement of the thyroid gland, resulting in a prominent swelling in the front of the neck. The normal human thyroid gland weighs 10 to 20 grams while some goitrous thyroid glands weigh as much as 1,000 grams. It is primarily because of the reduced secretion of TSH.
- **Graves disease :** It stands for endocrine disorder caused by hyperthyroidism (excess secretion of thyroid hormone) and thyrotoxicosis (effects of excess thyroid hormone action in tissue). It is an autoimmune disorder.
- **Gynaecomastia :** It refers to the enlargement of the breasts in the male, usually because of hormonal imbalance. The growth and development of male breasts is like that of the females breasts until puberty or even later.
- **Hashimoto disease :** It is an auto-immune disorder, *i.e.* a non-infectious form of the inflammation of the thyroid gland (thyroiditis).
- **Hypogonadism :** It is characterisied by little or no production of sex harmones. in men with decreased testicular function that results in testosterone deficiency and infertility. It is caused by hypothalamic, pituitary and testicular diseases.
- **Myxedema :** It is caused because of physiological reaction to lack of sufficient thyroid hormone (hypothyroidism) in the adult. It can be brought about by the removal of the thyroid for any cause, by a cessation of function of the gland, or simply by glandular atrophy.

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NERVOUS SYSTEM

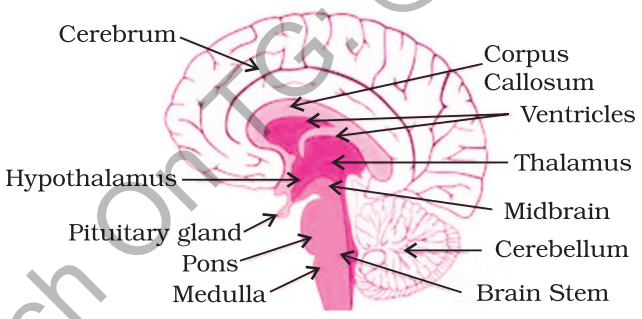
Nervous System

- Central Nervous System
- Peripheral Nervous System
- Autonomous Nervous System

Central nervous system (CNS): It includes :

- **Brain or Encephalon,** which occupies cranial cavity, and contains the higher governing centres.
- **Spinal cord or spinal medulla**, which occupies upper two-thirds of the vertebral canal, and contains many reflex centres.

- **Peripheral nervous system :** It is the somatic component of the nervous system, which includes :
  — 12 pairs of cranial nerves ; — 31pairs of spinal nerves.
- These nerves innervate the somatic structures of the head and neck, limbs and body wall, and mediate somatic sensory and motor functions.
- **Autonomic nervous system :** It is the visceral component of the nervous system, which includes:
  — sympathetic; — parasympathetic
- These being antagonistic helps a body interact with the environment for successful survival.
- **Brain, its parts and functions :** Brain for the convenience can be divided into three parts, called forebrain, mid brain and hind brain.
- **Forebrain :** It consists of cerebrum which is the largest part of the brain. It is divided into two hemispheres, cerebral hemispheres right and left. These are inter-connected by neural bridge called **corpous callosum.**The right side of the brain controls the left side of the body and vice versa. Also the hemispheres are divided in terms of what kind of thought they process or produce. The right is more concerned with the artistic, spatial and musical activities. The left is more concerned with linear, rational and verbal aspects.



Human Brain

It consists of :

- **The Frontal Lobe :** It is the centre for the command and control of a body being responsible for functions such as reasoning, problem- solving, judgement, impulse control. It also manages higher emotions such as empathy and altruism. This lobe is also involved in motor control and memory.
- **The Parietal Lobe :** It is involved in processing pain and touch sensation. It's also associated with cognition (including calculating location and speed of objects), movement, orientation, recognition and speech.
- **The Temporal Lobe :** It is involved in auditory (sound) sensation and is where the Primary Auditory Cortex and on the left hemisphere, Wernicke's Area (language recognition) are located. It is also involved in emotion, memory and speech.

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- **The Occipital Lobe :** It controls visual sensation and processing, being, the site of visual cortex in the brain.
- **Broca's Area :** It controls speech, language recognition and facial nerves.
- **The Hindbrain :** The parts of the hindbrain are:
- **Medulla Oblongata :** It helps control the body's autonomic functions (things you don't need to think about to perform) like respiration, digestion and heart rate. Also, acts as a relay station for nerve signals going to or from the brain.
- **The Pons :** It has roles in the level of arousal or consciousness and sleep. It relays sensory information to or from the brain along with being involved in controlling autonomic body functions. It also acts as a respiratory centre , hence, also called as pneumotaxic or shuttling centre.
- **The Cerebellum :** Mostly deals with movement. It regulates and coordinates movement, posture and balance. Hence, it is involved in learning movement.
- **The Limbic System :** It also called the "emotional brain" as where emotions reside and memory begins and unconscious value judgements are made. Information going through the Limbic System is filed under "agreeable or disagreeable". It also plays a role in salience (what grabs your attention), spontaneity and creativity. Located in the Limbic System are :
- **Amygdala :** It is almond-shaped, helps store and classify emotionally charged memories. It plays a large role in producing our emotions, especially fear. It's been found to trigger responses to strong emotions such as sweaty palms, freezing, increased heart-beat/respiration and stress hormone release.
- **Hippocampus :** Its primary role is in memory formation, classifying information, long-term memory. Like the RAM in your computer, it processes and stores new and temporary memory for long-term storage. It's also involved in interpreting incoming nerve signals and spatial relationships. It also deals with mix signals of smells and memories.
- **Hypothalamus :** It is linked closely with the pituitary gland to control many of the body's functions, hence, called super master endocrine gland. It monitors and controls circadian rhythms (daily sleep/wake cycle), homoeostasis being the thermoregulatory and osmoregulatory centre, appetite, thirst, other bodily demands. It also regulates respiration and heartbeats organises the behaviour related things.
- **Thalamus :** It acts as a relay station in the brain. Most of the sensory, auditory, visual and somatosensory (from your skin and internal organs) signals, go through it on their way to different parts of the brain for processing to elicit adequate response. It also regulates the activity of smooth muscles by coordinating motor signals.

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- **Spinal cord :** It is the main pathway for information connecting the brain and peripheral nervous system**. It's about 45 cm long in men and around 43 cm in women, is much shorter as compared to the length of the vertebral column being 13 mm thick in the cervical and lumbar regions to 6.4 mm in thoracic area.** In a human, it extends from the foramen magnum and continues through to the conus medullaris near the second lumbar vertebra, terminating in a fibrous extension known as the filum terminale. It act as the link between the brain and the nerves which spread through out the body.
- The spinal cord and brain are protected by three layers of membranes called meninges:
  1. **Dura mater :** It is the outermost protective layer. In between the dura mater and the surrounding bone of the vertebrae is a space called the epidural space filled with adipose tissue with a network of blood vessels.
  2. **Arachnoid mater :** It is the middle protective layer filled with cerebrospinal fluid (CSF). **The medical procedure known as alumbar puncture** (or "spinal tap") involves the use of a needle to withdraw cerebrospinal fluid from the subarachnoid space, In cross-section, the peripheral region of the cord contains neuronal white matter tracts containing sensory and motor neurons.
  3. **Pia matter :** It is the inner layer, close to the brain. It is moderately tough connective tissue.
- **Grey matter :** It lies internal to this peripheral region. The nerve cell bodies of the grey matter are contained in the three grey columns of the spinal cord that give the region its butterfly-shape. This central region surrounds the central canal, which is an extension of the fourth ventricle of the brain.
- **Functions of spinal cord :** It is responsible for:
- Electrical transmission and communication, the impulses as signals are conducted up and down the cord, allowing communication between different body-parts and the brain, since it runs through the different levels of the trunk section.
- Walking or any other movement that may seem simple has to be carefully coordinated by several groups of neurons known as central pattern generators in the spinal cord. These neurons send signals to the muscles in the legs, causing them to extend or contract, producing the alternating movements that are involved in walking.
- In the coordination of predictable involuntary responses to stimuli that involve the brain, spinal cord and nerves of the peripheral nervous system (PNS).
- **Reflex arc :** It is the pathway followed by sensory nerve in carrying the sensation from a receptor organ to the spinal cord and then the pathway followed by a motor nerve in carrying the order from the spinal cord to the effector organ during a reflex action.

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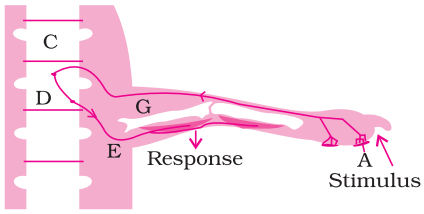
- In a reflex arc, an action potential never travels to the brain for processing and so results in a much quicker reaction. When a stimulus (A) is encountered, the signal from that stimulus will travel up the sensory neuron (B) to the spinal column (C). There, it will likely pass through a short interneuron (D) before continuing down a motor neuron (E) to the origin of the signal. Then, a contraction of the muscles (F) is triggered, moving the bone (G). as shown in the diagram below :



- **Spinal v/s Cranial reflexes :** A spinal reflex action is an automatic involuntary response to a stimulus coordinated by the spinal cord. An example : the way in which we respond to a stimulus is our reaction to touching a hot object (like a hot plate). Very quickly, and without thinking about it, we pull our hand away. However, when the reflex is coordinated by the brain mostly in voluntary mode, it is called cranial reflex.

Cranial nerves :

There are 12 pairs of cranial nerves as listed below in the table.

S.N.	Name	Function
I.	Olfactory nerve	Sensory, smell
II.	Optic nerve	Vision, each optic nerve contains a million nerve. (sensory)
III.	Oculomotor	Eye lens focal length (Power of accommodation) constriction or expansion of pupil's size. (mixed)
IV.	Trochlear	Smallest of the nerve , movement of the eyeballs by sending impulses to the superior oblique muscles which rotate the eyeballs in sockets.(mixed)
V.	Trigeminal	It is the largest cranial nerve and splits into the following 3 divisions: Ophthalmic nerve, Maxillary nerve and Mandibular nerve. These nerves control the facial muscles involved in chewing while sensory fibres convey the sensations of touch, pain and temperature from the front of the head including the mouth. (mixed)

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VI.	Abducens	Moves the eyeballs outwards by sending nerve impulses to the lateral rectus muscles.
VII.	Facial	Sensory fibres are concerned with taste via the taste buds at the front of the tongue while motor fibres control the secretion of tears and saliva as well as facial expressions.
VIII.	Vestibulocochlear/	It has two branches , vestibular and cochlear.
	Auditory	Cochlear is the nerve of hearing while vestibular regulates information about posture, movement and balance.
IX.	Glossopharyngeal	Motor fibres modulate swallowing via supply to the muscles of the throat (pharynx) area.
X.	Vagus	It supplies to thoracic and abdomen region. Stimulates voluntary muscles that affect swallowing, coughing and speech, stimulates the secretion of digestive fluids. It also monitors the level of oxygen and carbon dioxide in blood.
XI.	Accessory	Spinal Parts: Governs the movement of the head and shoulders while cranial parts controls swallowing movements.
XII.	Hypoglossal	Supplies the muscles of the tongue; responsible for the tongue movements involved in speech and swallowing.

- **Spinal nerves :** Cervical: 8 pairs, thoracic: 12 pairs, lumbar-5 pairs, sacral- 5 pairs and coccygeal-1 pair. This gives a total of 31 pairs present in body.
- **Autonomous nervous system :** It is self-governed system mainly coordinates body's internal environment. It acts largely unconsciously and regulates bodily functions such as the heart beat rate, digestion, respiratory rate, pupillary response, urination and sexual arousal. This system is the primary mechanism in control of the fight-or-flight response and the freeze-and-dissociate response. It has two branches: the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system is often considered the "fight or flight" system, while the parasympathetic nervous system is often considered the "rest and digest" or "feed and breed" system. In many cases, both of these systems have "opposite" actions where one system activates a physiological response and the other inhibits it.

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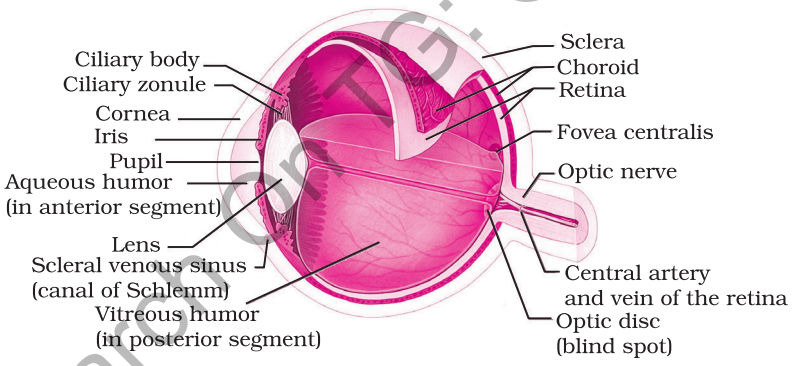
Structure of human eye and functions: The eye is a slightly asymmetrical globe, about one inch (2.5 cm) in diameter. Located in the bony socket, called 'orbits'. The front part of the eye (the part you see in the mirror) includes the :

- **iris** (the pigmented part)
- **cornea** (a clear dome over the iris)
- **pupil** (the black circular opening in the iris, which lets light in)
- **sclera** (the white part,outermost dead layer)
- **conjunctiva** (It is the thin transparent, clear layer of tissue covering the front of the eye, except the cornea) Just behind the iris and pupil lies the lens, which helps to focus light on the back of the eye. Most of the eye is filled with a clear gelatinous material, called the **vitreous**. Light projects through the pupil and the lens to the back of the eye *i.e.* photoreceptor layer. The inside lining of the eye is covered by special light-sensing cells, together called the **retina**. The retina converts light into electrical impulses. Behind the eye, the optic nerve carries these impulses to the brain. The macula is a small sensitive area within the retina that gives central vision. It is located in the centre of the retina and contains the fovea.



Eye colour is created by the amount and type of pigment in the iris. Multiple genes inherited from each parent determine a person's eye colour.

The human eye works much like a digital camera:

- Light is focused primarily by the cornea the clear front surface of the eye, which acts like a camera lens.
- The iris of the eye functions like the diaphragm of a camera, controlling the amount of light reaching the back of the eye by automatically adjusting the size of the pupil (aperture).
- The eye's crystalline but flexible lens is located directly behind the pupil and further focuses light. Through a process called

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accommodation, this lens helps the eye automatically focus on near and approaching objects, like an autofocus camera lens.

- Light focused by the cornea and crystalline lens (and limited by the iris and pupil) then reaches the retina the light-sensitive inner lining of the back of the eye. The retina where the real, inverted and diminished image is formed acts like an electronic image sensor of a digital camera, converting optical images into electronic signals. The optic nerve then transmits these signals to the visual cortex the part of the brain that controls our sense of sight.

Human eye defects : The two main defects of the human eye are:

- Myopia or nearsightedness, the affected person can see nearby objects but not distant objects as the image formation takes place in front of the retina. It is corrected by wearing glasses having concave lenses.
- Hypermetropia or far sightedness; the affected person can see distant objects but not nearby objects as the image formation takes place behind the retina. It is corrected by wearing glasses having convex lenses.
- Astigmatism is caused because of the uneven surface of cornea such that the image is not clear. It can be treated by wearing cylindrical lens glasses or undergoing surgery.
- Conjunctivitis is commonly referred to as pink eye. It happens due to imflammation of conjunctiva that covers the cornea and that lines the eyelids due to an allergy or viral and bacterial infections.
- Amblyopia is also known as having a lazy eye. It happens when the brain prefers one eye over the other in functioning. Amblyopia may happen for a number of reasons, such as strabismus which causes one or both eyes to turn inward. There are many ways to treat amblyopia, such as glasses, surgery, eye drops and wearing a patch to strengthen the eye muscles.
- Glaucoma is caused by the deterioration of the optic nerve. There are several things that can cause this disorder, such as infection, injury, increased intraocular pressure due to certain conditions like diabetes and other conditions lack of Vitamin D. Glaucoma can be treated with surgery or special eye drops.
- Cataract is caused by a protein buildup that makes the eye lens cloudy. Some of its causes include age, trauma to the eye and medical conditions such as diabetes. Cataracts are normally treated with surgery but can also be treated by wearing bifocal lenses.
- **Human ear :** The human ear can be studied under outer, middle and internal ear being its three parts.

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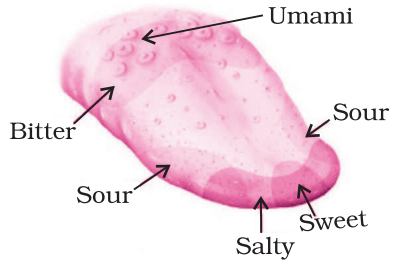
- The outer ear is called the pinna and is made of ridged cartilage covered by skin. Sound funnels through the pinna into the external auditory canal, a short tube that ends at the eardrum (tympanic membrane).
- Sound causes the eardrum and its tiny attached bones in the middle ear to vibrate, and the vibrations are conducted through endolymph in the nearby cochlea. The spiral-shaped cochlea is part of the inner ear. Organ of corti in it transforms sound into nerve impulses that travel to the brain.
- The fluid filled semicircular canals (labyrinth) attach to the cochlea and nerves in the inner ear. They send information on balance and head position to the brain. The eustachian (auditory) tube drains fluid from the middle ear into the throat (pharynx) behind the nose.

The human ears are sensitive to the sound waves of frequency 20Hz to 20KHz called the audible limit.

- **Human tongue and taste:** Taste is the gustatory sensation produced when a substance in the mouth reacts chemically with taste receptor cells located on taste buds in the oral cavity, mostly on the tongue. Tongue, along with smell (olfaction) and trigeminal nerve stimulation, determines the flavours of food or other substances. Humans have taste receptors on taste buds (gustatory calyculi) and other areas including the upper surface of the tongue and the epiglottis.
- The tongue is covered with thousands of small bumps called papillae, which are visible to the naked eye. Within each papilla are hundreds of taste buds. The exception to this is the filiform papillae that do not contain taste buds. There are between 2000 and 5000 taste buds that are located on the back and front of the tongue. Others are located on the roof, sides and back of the mouth, and in the throat. Each taste bud contains 50 to 100 taste receptor cells.



- The sensation of taste includes five established basic tastes: sweetness, sourness, saltiness, bitterness and umami. Umami is a type of savoury taste with buds present at the back of tongue.

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Chapter 7

PLANT AND ANIMAL REPRODUCTION

Asexual modes of reproduction ,vegetative propagation in plants, parthenogenesis in animals, pollination and types, double fertilization, development of seed and fruits, parthenocarpy and polyembrony. Human structure of male reproductive system, development of sperm, menstrual cycle in females, fertilization and development of embryo, parturition, contraceptive methods, techniques under ART.

PLANT REPRODUCTION

BIOLOGY

Plants have been successful over generations despite their inability to move because of the varieties of ways they can reproduce. All these forms of reproduction being adopted by plants have broadly been classified into two types, asexual reproduction and sexual reproduction.

Types of Asexual Reproduction in Plants :

- **Asexual reproduction :** It requires only one parent. Since there is only one parent, there is no exchange of genetic information, and the offspring are clones (identical copies) of the parent.
- Asexual reproduction in plants can occur in a variety of forms, including budding, vegetative propagation and fragmentation.
- **Budding :** It refers to the development of a plant from a bud such as eyes (small depressions) in a potato. Each of these, if planted under suitable conditions sprouts to grow into a clone of the mother plant.
- **Fragmentation :** It's a type of asexual reproduction often used by nurseries and greenhouses for producing plants quickly. For many plants, a clone can be created by the breaking off a portion of the stem and placing it in soil or water, depending on the plant. This also happens naturally in filamentous algae or in liverworts. In liverwort plants, when small stems or leaves are often broken off by animals or wind , each part sheds from a plant and grows into a clone of the parent plant when it lands in the soil.
- **Vegetative propagation :** Vegetative propagation or vegetative reproduction is the process of multiplication in which a portion of the fragment of the plant body functions as propagule and develops into a new individual. Some plants are able to multiply by vegetative methods, which involve the production of new plants without the act of fertilization. The vegetative propagation can be natural or artificially induced. In which the organs like root, stem, leaf and even buds are variously modified to grow into a plant.

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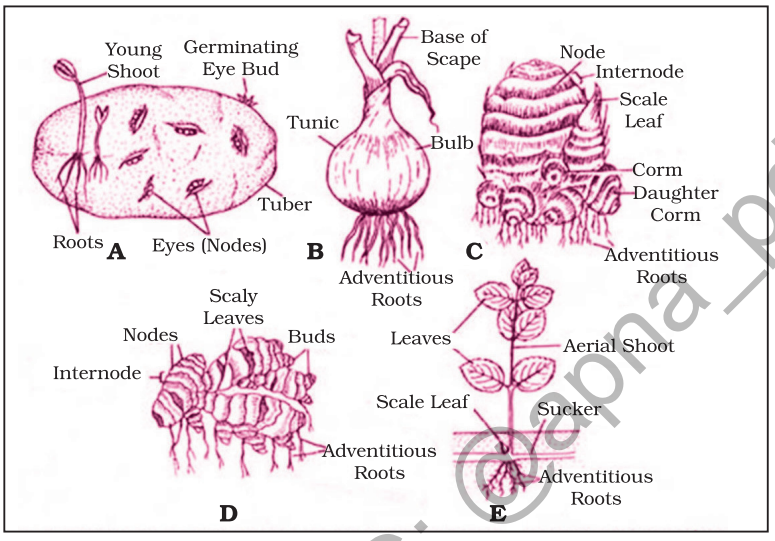
- **Natural vegetative propagation :** It occurs when an axillary bud grows into a lateral shoot and develops its own roots (also known as adventitious roots). Plant structures allowing natural vegetative propagation include bulbs, corm, rhizomes, stolons and tubers.



- **Bulbs :** These are lateral buds, such as daffodils, from the base of the mother bulb, which produce new smaller bulbs or bulbils in subsequent years. e.g. tulips
- **Rhizomes :** These are root-like stems that grow horizontally under the ground. New roots and shoots form at the nodes with shoots growing upwards to form new plantlets. Lateral buds grow out to form new rhizomes. Examples include iris and root ginger, turmeric, grasses, weeds etc.
- **Stolons or runners :** They are horizontal stems that grow above the ground, for example, strawberries. Tiny plantlets form along the stolon and roots from where they touch the ground. When the connection with the parent plant breaks, the new plant becomes independent. They may develop adventitious roots.
- **Tubers :** These are swollen portions of an underground stem that store food, so a plant can lie dormant over winter, for example, potatoes. Auxillary buds, commonly known as 'eyes', form over the surface of the tuber and produce shoots that grow into a new plant the following year.
- **Artificial vegetative propagation:** Horticulturalists and gardeners use vegetative propagation methods that plants don't use naturally. These methods involve taking a piece of one parent plant and causing it to regenerate itself into a new plant. Common methods include cuttings, grafting and budding, and tissue culture.

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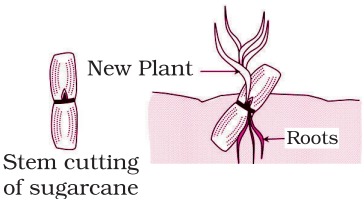
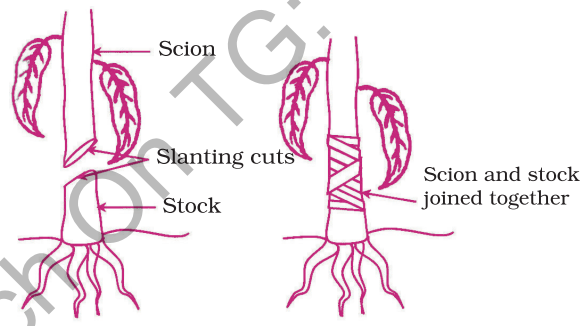
- **Cutting :** A cutting is a piece that has been cut off a mother plant and then caused to grow into a whole plant. Often this involves a piece of stem that is treated with rooting hormones to encourage new roots in order to form before planting. Ex. Rose, sugar cane croton, tapioca, China rose. Sometimes root cuttings with buds on them will produce new shoots when pressed directly into soil such as in rose, lemon, tamrind etc.



Cutting

- **Grafting and budding :** Grafting is generally carried out in plants which donot root easily, or have weak root system. It involves joining a stem piece (as in grafting) or a single bud (as in budding) onto the stem of a plant that has roots.



Artificial vegetative propagation by grafting

The stem piece or bud is called the scion, and the plant with roots is called the stock. Grafting is commonly used for producing fruit trees sometimes with more than one variety of the same fruit species growing from the same stem. Ex. mango, apple, guava, citrus etc.

- **Tissue culture:** Using tissue culture, sometimes called micropropagation, the tiny fragments of plants are treated with plant hormones such as auxin and cytokinin in a sterile growing medium. The hormones stimulate the growth of a callus, from which a new seedling can grow. This method is used for producing large numbers of identical seedlings.

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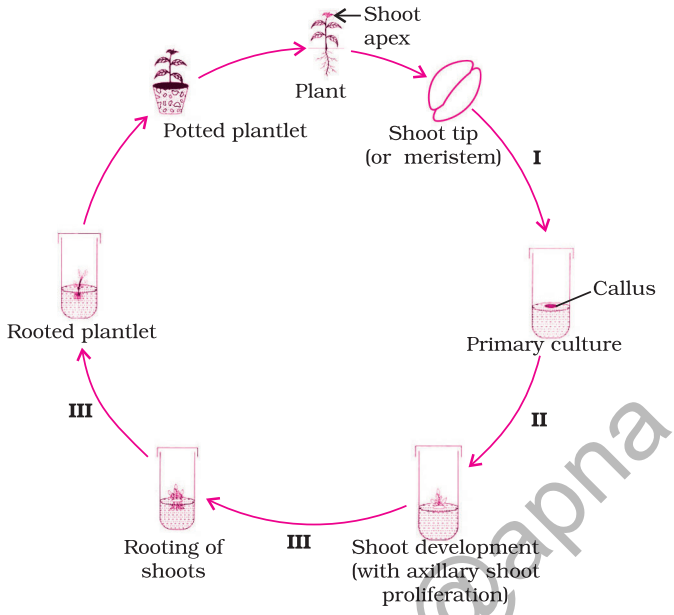

Tissue Culture

Advantages of Asexual Reproduction in Plants : The advantages of asexual reproduction include.

- the rate of growth is fast as it does not involve any gamete formation and fertilization. The propagation of a new plant from, a mother plant becomes faster.
- the retaining of the desired characteristics over the generations as the offspring plants are clone to the mother plant.
- propagation of plants in which the seeds produced are inviable (non- germinating) such as in lemon, oranges, etc.
- propagation of plants which do not produce any reproductive appendage in their life time such as sugar cane.
- propagation of plants having small populations because if there is a small population of plants in a secluded area, there may not be an adequate number of plants to pollinate one another. In this instance, it is advantageous for a plant to be able to reproduce vegetatively.

Sexual reproduction in plants : Flower are the reproductive appendages that are borne on the shoots of a stem. They bear male and female reproductive structures called androecium and gynoecium respectively.

- **Androecium** are male reproductive organs bearing stamens. Each stamen consists of a slender stalk, the filament and the tetragonal bilobed anther.

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- **Gynoecium or Pistil :** Are female reproductive organs. Pistil are composed of one or more carpels while each carpel consists of three parts: Stigma, Style and Ovary. The ovary contains one or more ovules or megasporangia.
- **Monoecious :** These are the plants that bear the flowers of both sexes, e,g, maize, alder trees, birch trees, pine trees, spruce trees, beech trees, walnut trees and cypress trees.
- **Dioecious :** Denoting a plant species in which male and female flowers are borne on separate individuals, e.g. papaya , date palm, mulberry plants, holly plants, juniper trees, maple trees, ash trees, persimmons trees, willow trees, mountain holly trees and the kiwi fruit vine.
- **Pollination and types :** The term pollination refers to the transfer and deposition of pollen grains on the stigmatic surface of the flower. It can be self or cross pollination. Each flower is well adopted and modified for its mode of pollination.
- **Cleistogamous flowers :** These are flowers in which pollination takes place during bud stage, *i.e.* prior to the opening of bud such as in peanuts, peas and beans. However, this behaviour is most widespread in the grass family with the largest genus of cleistogamous plants is being *Viola*.
- **Types of cross pollination :** Pollination based on the agency involved in the transfer of pollen grains from anther to stigma is of the following types:

Technical Term	Agencies of	Technical Term Pollination	Agencies of Pollination
Anemophily	Wind	Malacophily	Snails
Entomophily	Insects	Hydrophily	Water
Ornithophily	Birds	Chiropterophily	Bats
Myremecophily	Ants	Zoophily	Higher animals

- **Development of pollen grains :** In flowering plants, pollen grains are formed within the anther. It is the first cell of a male gametophyte.
- As the anther matures, pollen sacs possessing microsporocytes begin to develop through cell division. The microsporocytes change to form clusters or groups of four called quartets within the four chambers.
- As the anther matures, the pollen sacs walls between adjacent pairs break down, creating two sacs instead of four.
- The microspores within the chambers are almost ready to become pollen grains but first they undergo three more changes which occur almost simultaneously.

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1. Separation of the members of the quartets from one another.
2. nuclear division forming two nuclei that develop as the generative nucleus and the vegetative nucleus. They are involved in how the pollen grain achieves fertillization.
3. development of two layered wall intine and exine around each microspore. Exine contains sporopollenin developed from Ubisch's granules which make pollen grain resistant to chemicals, temperature and also contribute in their fossilization.

- **Development of ovule :** In flowering plants, the ovule ("small egg") is the structure that gives rise to and contains the female reproductive cells. It consists of three parts: the integument(s) forming its outer layer(s), the nucellus (remnant of the megasporangium), and female gametophyte (formed from haploid megaspore) in its centre. The female gametophyte specifically termed a mega gametophyte is also called the embryo sac in angiosperms. The mega gametophyte produces an egg cell (or several egg cells in some groups) for the purpose of fertilization. After fertilization, the ovule develops into a seed.
- **Double fertilization in flowering plants :** It is a complex fertilization mechanism of flowering plants (angiosperms) as it involves the joining of a female gametophyte (mega gametophyte, the embryo sac) with two male gametes (sperm).
- It begins when a pollen grain adheres to the stigma of the carpel. The pollen grain after successful compatibility interaction absorbs moisture and begins to germinate, forming a pollen tube that extends down towards the ovary through the style. The tip of the pollen tube then enters the ovary and penetrates through the micropyle opening in the ovule. The pollen tube proceeds to release two sperms in the mega gametophyte (**An eight-nucleated and seven-celled structure).**
- One sperm fertilizes the egg cell and the other sperm fuses with the two polar nuclei of the large central cell of the mega gametophyte. The haploid sperm and haploid egg fuse to form a diploid zygote (syngamy) while the other sperm and the two haploid polar nuclei of the large central cell of the mega gametophyte form a triploid nucleus (triple fusion). The large central cell of the gametophyte develops into the endosperm, a nutrient-rich tissue, to provide nourishment to the developing embryo. The ovary, surrounding the ovules, develops into the fruit, which protects the seeds and may function to disperse them.
- **Embryo :** It is structure that develops from a fertilized egg having radicle (future root) and plumule(future shoot) and a pair of secondary nuclei form primary endosperm nucleus that develops into endosperm to carry stored food required for embryo development and at the time of seed germination.

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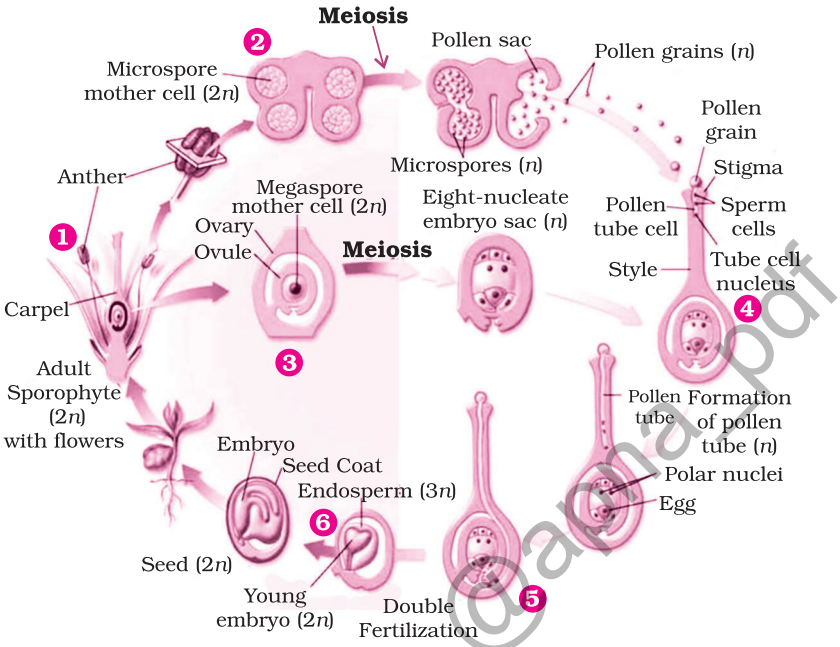

- **Parthenocarpy :** It (literally meaning virgin fruit) is the natural or artificially induced production of fruit without the fertilization of ovules *i.e.* seedless fruit. In some plants pollination or other stimulation is required for parthenocarpy. This is termed as **stimulative parthenocarpy**. This can also induced by application of hormones like auxin and cytokinin in amout of 10^{-7}m each. e.g. in tomato. The plants that do not require pollination or other stimulation to produce parthenocarpic fruit have **vegetative parthenocarpy**. Seedless cucumbers are an example of vegetative parthenocarpy while a seedless watermelon is an example of stenospermocarpy. Varieties of the pineapple, banana, cucumber, grape, orange, grapefruit, persimmon, and the breadfruit are the examples of naturally occurring parthenocarpic fruits.
- **Polyembryony :** It refers to the occurrence of two or more embryos in an ovule. It was first noted in the seeds of an orange by Leeuwenhoek (1719). In a seed with many embryos, only one develops while others degenerate during the course of development. However, based on the mode of development, it can be :
- **Cleavage polyembryony :** It being common in gymnosperms involves the cleavage of the zygote or earlier stages of development (pro-embryo) into two or more units such as *Nicotiana rustica, Lobelia, Erythronium*, etc.
- Embryo from cells other than the egg cell such as from synergids or antipodal cells.
- Embryo arising from cells outside embryo sacs.

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- Embryos from endosperm particularly from the egg, not embedded in endosperm.
- Polyembryony can be spontaneous or induced spontaneous is natural occurring polyembryony which can be gametophytic or sporophytic.Gametophytic is when the embryo develops from the gametic cell of embryo sac while sporophytic is one which the embryo develops from the somatic cell of embryo sac such as nucellus or integument.
- Induction of polyembryony is advantageous as nucellar embryos are resistant to diseases and exhibit better growth than cutting in citrus plants.
- **Endospermic seeds and non-endospermic seeds :** The endospermic seed are the seeds which possess a part of endosperm even after the development of an embryo hence are also called albuminous seeds such as castor, wheat, maize and barley. Seeds are non-albuminous plants when they do not carry any endosperm. Instead, they develop cotyledon such as pea, bean, gram and groundnut.
- **Seed germination :** Germination is the process of seeds developing into new plants after a period of dormancy or unavailability of suitable conditions for germination. First, environmental conditions must trigger the seed to grow. Usually, this is determined by how deep the seed is planted, water availability and temperature. When water is plentiful, the seed gets filled with water by a process called imbibition. The water activates enzymes, that begin the process of seed growth. The seed grows a root to access water underground. Next, the shoots, or growth above ground, begins to appear. The seed sends a shoot towards the surface, where it will grow leaves to harvest energy from the sun. The leaves continue to grow towards the light source in a process called photomorphogenesis.
- Several factors influence seed germination. The most important factors are water availability, oxygen availability, temperature and in some cases, sunlight where response to light is mediated by phytochrome. The seeds which need light for germination are called photoblastic seeds such as those of lettuce, tomato and datura.
- **Epigeal v/s Hypogeal germination :** In hypogeal germination, the cotyledons emerge from the seed containing enough nutrients to fuel seed development and are not photosynthetic. These seeds are usually larger than epigeal seeds. As the seedling grows, its shoot rises above ground level, while the cotyledons remain below or at ground level. In this, the primary source of energy for growth is endosperm e.g., in wheat, maize, pea, coconut, etc.
- In epigeal germination, the cotyledons emerge and rise above ground level as the seedling grows. They may also serve a photosynthetic role in seedling development. The seedlings that develop this

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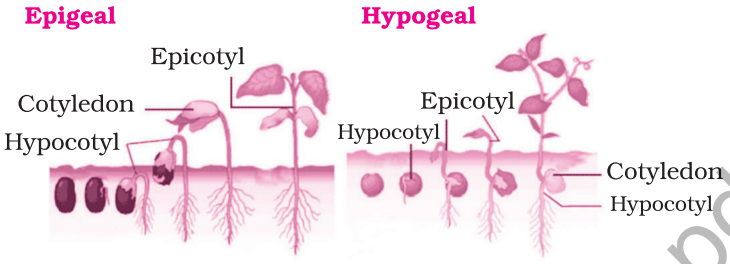
way quickly form a shoot and leaves, both of which perform photosynthesis to fuel further development. Here, the cotyledons are the primary source for growth e.g., in castor, beans and sunflower.



HUMAN REPRODUCTION

Male reproductive system : The male reproductive system includes the scrotum, testes, spermatic ducts, sex glands and penis. These organs work together to produce sperm, the male gametes, and the other components of semen. These organs work together to deliver semen out of the body and into the vagina where it can fertilize egg cells to produce offspring.

- **Scrotum :** It is a sac-like organ made of skin and muscles that houses the testes in two pouches with one testis in each. The testes are extra abdominal in scrotum because the development of sperm requires about 3°C less temperature than body temperature.
- **Testes :** The testes, also known as testicles, are the male gonads responsible for the production of sperm by spermatogenesis and secretion of testosterone (Male sex hormone).
- Spermiogenesis is the transformation of non-motile spermatid into a mature motile spermatozoa capable of fertilizing an ovum.
- **Epididymis :** It is the sperm storage area that wraps around the superior and posterior edge of the testes.
- **Seminal vesicles :** These are the pairs of glands which secrete sugar fructose and mucus to provide swimming medium to the coming sperms in vas deferens. About 70 percent of semen is contributed by the seminal vesicles.
- **Ejaculatory duct :** It passes through the prostate gland and joins the urethra. The prostate glands are known to secrete an alkaline secretion to neutralize the acidity of urine through urethra.
- **The bulbourethral gladns :** (Cowper's glands) These small glands are located proximal to membranous urethra which also opens into the urethra.

  They are tubulo-alveolar glands which secrete clear mucus for lubrication in the urethra.

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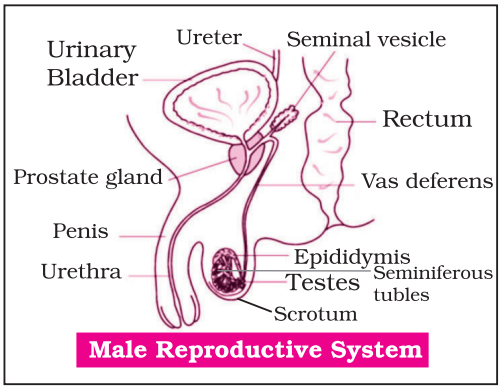
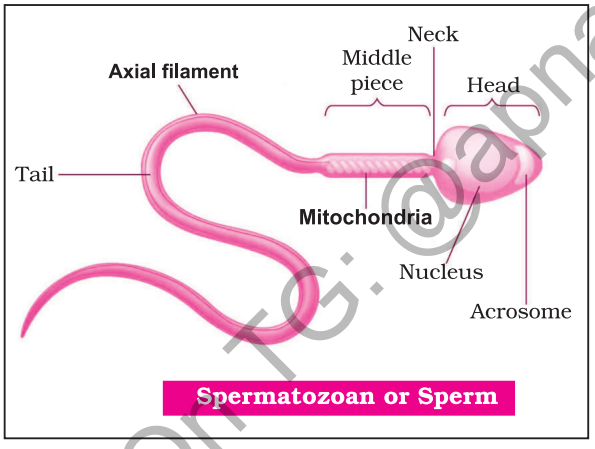
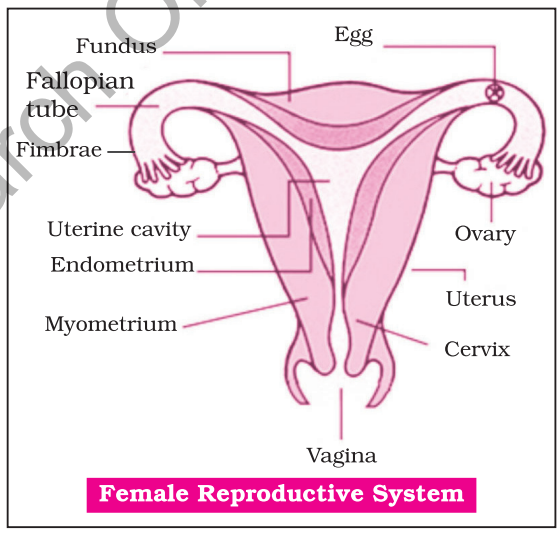


Male Reproductive System



Spermatozoan or Sperm



Female Reproductive System

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- **Female reproductive system :** The female reproductive system includes both external and internal organs. The internal organs are the uterus, fallopian tubes, and the ovaries. The ovaries produce the ova (egg cells) and sex hormones (estrogen and progesterone). The fallopian tube carries the produced ovum after ovulation on the 14th day of menstrual cycle for fertilization while uterus is the pear-shaped hollow structure where the development of embryo and foetus takes place after successful fertilization during the gestation (pregnancy) period of 270 days. The external sex organs are also known as the *genitals* and these are the organs of the vulva including the labia, clitoris and vaginal opening. The vagina is connected to the uterus at the cervix.
- **Menstrual cycle :** It is a woman's monthly cycle that ends with bleeding on every 28th day. in most menstrual periods that lasts from 3 to 5 days involves the shedding of the lining of the uterus along with dead ovum. A woman normally loses about 70-80 ml of blood during a single period and, therefore, is more prone to suffer from anaemia.
- **Menarche v/s Menopause :** Menarche refers to the first menstrual cycle a girl experiences that marks the onset of puberty at an age of about 12 years. Menopause is the last menstrual cycle that a female experiences that marks the end of adulthood at an age of about 50 years.
- **Ovarian changes in menstrual cycle :** During menstrual cycle in the first half of the cycle, levels of estrogen rise making the lining of the uterus grow and thicken. This lining of the womb (uterus) is a place that nourishes the embryo if pregnancy occurs. At the same time, the lining of the womb is growing, an egg ovum in one of the ovaries start to mature. At about day 14 of an average 28-day cycle, the egg leaves the ovary in so-called ovulation under the effect of hormone LH from pituitary gland to be a fallopian tube where the fertilization takes place. The graafian follicle after ovulation forms corpus luteum that takes over the function of the secretion of progesterone , the so called pregnancy hormone.

A woman is most likely to get pregnant during the 3 days before or on the day of ovulation with the presence of a live ovum in the fallopian tube (Danger/Fertile Geriod).

- A woman becomes pregnant if the egg is fertilized by a man's sperm cell and attaches to the uterine wall. In such a case, the hormone **progesterone from ovary called pregnancy hormone** takes over the regulation of the development of uterine wall and other associated changes. If the egg is not fertilized, it will break apart and shed off during the menstrual period.

Hormonal regulation of menstrual cycle : The events which occur during the course of a single menstrual cycle are under well control of hormones from pituitary gland and ovaries.

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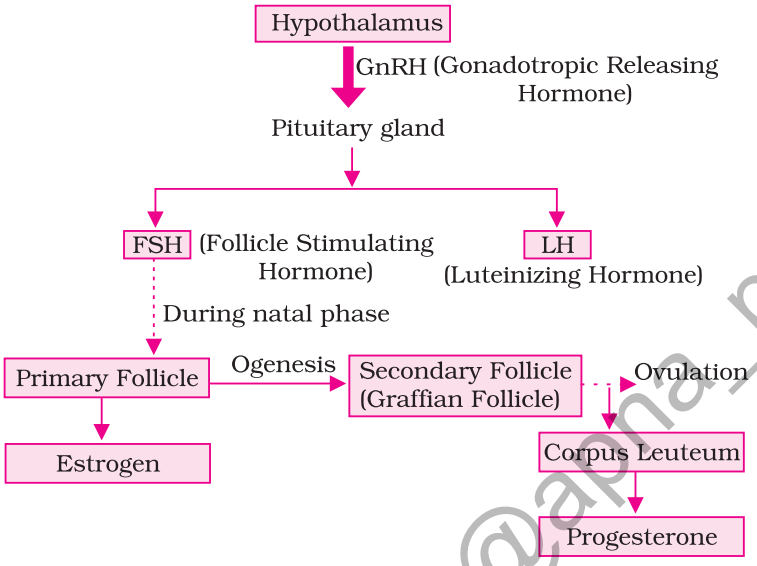
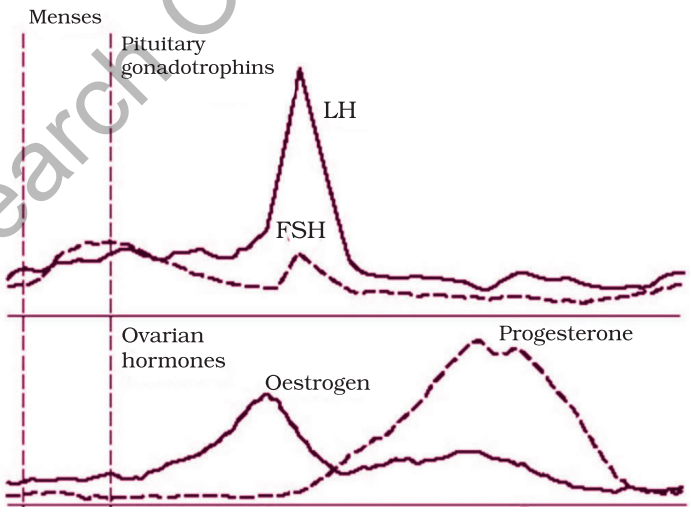
Hormonal Coordination in Menstrual cycle



- For the first 14-days oestrogen regulates the development of ovum until the 14th day :
- On the 14th-day ovulation takes place under the influence of LH from pituitary gland.
- The 15th-day onward until the start of menstrual period progesterone regulates the developmental changes in ovary and uterus.



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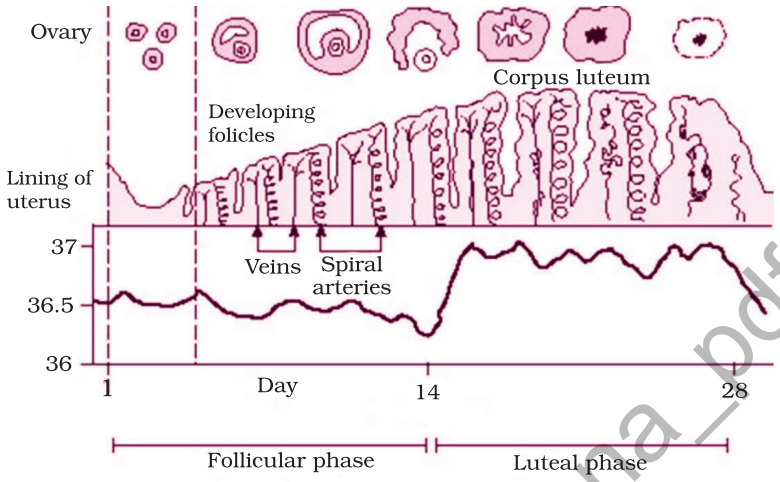

Placenta : It is a connection between the foetal membrane and the inner uterine wall. Thus, human placenta is partly maternal and partly embryonic. By means of placenta the developing embryo and developing foetus:

- helped to get oxygen from the maternal blood and in the removal of CO_2 into the maternal blood.
- excretion of nitrogenous waste products produced in the embryo.
- in gaining immunity from the mother against certain diseases like measles, small pox, diphtheria, etc.
- in the transport of pathogens like viruses diffuse through the placenta. Viruses causing measles, rubella, small pox and AIDS may infect the foetus.
- gets drugs such as the drug thalidomide used for avoiding nausea and morning sickness during early pregnancy by some women results in the birth of a deformed child.
- is exposed to the secretion of hormones such as relaxin , HCG, progesterone, etc.

Parturition : The process of childbirth is known as parturition. It involves :

- onset of childbirth with labour pains followed by the dilation of the cervix.
- expulsion of amniotic fluid followed by the baby's birth through the birth canal *i.e.* vagina.
- the detachment of umbilical cord and placenta once the infant has wept to open the respiratory tract.

Lactation : It stands for the feeding of the baby with the mother's milk. The first milk which comes out from the mother's mammary

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glands just after childbirth is known as **colostrum.** It is rich in calories and proteins and contains antibodies that provide passive immunity to the new-born baby.

Lactation amnnorhoea : It is a period of 3-6 months after childbirth when a mother does not experience any menstrual cycle. It occurs to use body resources in the breastfeeding of a child.

Contraceptive methods : Contraceptive methods include the methods adopted by a couple to prevent conception. These methods can be roughly divided into five types :

- Hormonal methods: combined hormones (pill, patch, u-ring) progestin-only (Depo-Provera, progestin-only pill)

Saheli is the recently developed non-steroidal contraceptive pill by CDRI (Central Institute of Drug Research) Lucknow, India. It is once a-week pill that blocks the secretion of estrogen in ovary, hence, makes unable the uterus to prepare for implantation.

Barrier methods (chemical and physical): condoms (male condom, female condom), spermicides (VCF, foam, gel, sponge), diaphragm and cervical cap.

- **Surgical methods :** These include sterilization by adopting vasectomy(male) and tubectomy (tubal ligation) (female).
- Intrauterine Device (IUD) (Copper-T & Hormonal control)
- Natural Methods: Abstinence, fertility awareness method (FAM), lactational amenorrhoea method (LAM)
- **ART (Assisted Reproductive technology) :** It's a developed technology to help a couple bear a child which they otherwise find difficult. It includes:
- **Intrauterine Insemination (IUI) :** It involves in the placement of a man's sperm into a woman's uterus or fallopian tube.
- **In Vitro Fertilization :** During *in vitro* fertilization (IVF), eggs and sperm are taken from the couple and are incubated together in a dish/test tube) in a laboratory to produce an embryo. A health-care provider then places the embryo into the woman's uterus, where it may get implanted and result in a successful pregnancy, in a mother or surrogate mother.

The world's first "test-tube baby" Louise Joy Brown was born on July 25, 1978, in Oldham, England. Her birth was by Caesarian section.

Harsha Chawda, India's first test-tube baby, was born in 1986 at Jaslok Hospital, Mumbai, Her birth was by Caesarian section under the supervision of the IVF specialist Dr Indira Hinduja.

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Chapter 8

HEREDITY AND VARIATION

Mendel's laws of inheritance , test cross, autosomes and sex chromosomes, mutation, pedigree analysis, DNA structure and functions: replication, transcription and translation, genetic code, sex determination and DNA finger printing or DNA profiling.

BIOLOGY

- **Heredity :** It refers to the transmission of the so called traits of characters from parents to offspring in all, sexually and asexually reproducing organisms.
- **Inheritance :** It refers to an act of acquiring traits from a parent(s) by an offspring. It involves the physical features such as eye colour, shape of nose and mouth, height and other distinguishing physical characteristics.
- **Genetics :** It is the field of biology that deals with the study of genes, genetic variations, and heredity in living organisms. Gregor Mendel, who first proposed the laws of inheritance is considered as the father of genetics with trait inheritance and molecular inheritance mechanisms of genes still being the primary principles of genetics in the 21st century along with the study of function and behaviour of genes.

Reasons for selection of pea plant by Mendel : Gregor Mendel choose pea plants for his experiments because they

- are easy to raise, have many offspring per mating,
- with bisexual flowers can undergo self-pollination and by emasculation can be induced to cross pollinate.
- have varieties in genotype and phenotype that are easily observable such as plant size, pea colour, type of seed, smooth or wrinkled , position of flower, etc. The hybrids of garden pea are perfectly fertile and there were no intermediate characters.
- **Seven contrasting traits in pea plant** : The seven different contrasting traits in pea plants *(Pisum sativum)* are:
  - Pea shape (round or wrinkled)
  - Pea colour (green or yellow)
  - Pod shape (constricted or inflated)
  - Pod colour (green or yellow)
  - Flower colour (purple or white)
  - Plant height (tall or dwarf)
  - Position of flowers (axial or terminal)
- **Allele :** Each of two or more alternative forms of gene is called an allele. It is also called as Alletomorphs'.
- **Dominant/ Recessive:** An allele whose expression overpowers the effect of a second form of the same gene is called dominant but an allele whose effects get concealed in an offspring by the dominant allele in the pair is called recessive.
- **Heterozygous/ Homozygous:** A condition in which two alleles for a given gene are different from each other. In homozygous, a condition in which two alleles for a given gene are the same.

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- **Rediscovery of Mendel's work:** : Gregor John Mendel in 1860 working on a pea plan proposed three laws: the Law of Dominance , the Law of Segregation and the Law of Independent Assortment. However, at the time when he proposed , the laws were not much accepted until 1900 when they were rediscovered a generation after Mendel had published his papers. The three botanists Hugo De Vries, Carl Correns and Erich von Tschermak working independently rediscovered Mendel's work.

Laws of Inheritance

	Name of Law of Inheritance	Statement
I.	Law of dominance	It states that in an organism, some alleles are dominant while the others are recessive. It is always the dominant allele that expresses itself pheotypically. The character that appears in F_1 generation is called dominant.
II.	Law of segregation	The first law to be rediscovered is also called the law of the purity of gametes (genes) It states that during gamete formation, the alleles for each gene separate from each other so that each gamete may carry only one allele for each gene.
III.	Law of independent assortment	It states that genes for different traits segregate independently hence, exhibit different traits in an offspring.

- **Mendelian ratio :** Mendelian ratio refers to the ratio of the genotypes in the offspring carrying a particular trait of a character which they inherit from their parents. (Also called as monohybrid ratio)
- In a **monohybrid** cross involving only one character, the F-1 ratio is 4:0 while the phenotypic ratio in F-2 ratio is 3:1 and genotypic ratio is 1:2:1 provided that the parents are homozygous for the contrasting trait of a character.

Tall TT — Dwarf tt

	t	t
T	Tt	Tt
T	Tt	Tt

4:0

Tall TT — Dwarf tt

	t	t
T	Tt	Tt
t	tt	tt

1:1

- In a dihybrid cross involving two characters, the F-1 ratio is 4:0 while the phenotypic ratio in F-2 generation is 9:3:3:1 and in a trihybrid cross ,the ratio is 27:9:9:9:3:3:3:1.

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- **Test cross :** It is a cross carried out to find the genotype of a plant. (especially of F_1 generation). The cross involves the cross of the subject plant with the plant which is homozygous recessive for a character(s). The ratio of 1:1 proves heterozygous condition while the ratio of 4:0 expresses the homozygous condition for the trait of the character(s).

Monohybrid cross

Mother is heterozygous for a particular trait (Aa).

Father is also heterozygous for the same trait (Aa).

Homozygous dominant (AA) = 1/4
Heterozygous (Aa) = 1/2

♀ ♂	A	a
A	AA	Aa
a	Aa	aa

Dihybrid Cross (Gene Linkage)
A and z represent one trait, and B and b represent a different trait that is linked to inheritance of A or a.

♀ ♂	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Dominant for A and B = 9/16
Recessive for a, dominant for B = 3/16
Dominant for A, recessive for b = 3/16
Recessive for a, recessive for b= 1/16

Incomplete dominance : It is a form of intermediate inheritance in which one for a specific trait is not completely expressed over its paired allele. This results in a third phenotype in which the expressed physical trait is a combination of the phenotypes of both alleles. Examples of incomplete dominance are:

- A snapdragon flower that is pink as a result of cross-pollination between a red flower and a white flower when neither the white nor the red alleles are dominant.
- A child with wavy hair as a result of one parent's curly hair and the other's straight hair.

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- A black sheep and a white ram (male of sheep) mate and have a grey sheep or when a black bitch (female of dog) and a brown dog mate and the result is a dog with a brindle coat.
- A long-tailed dog and a short-tailed bitch mate and the offspring has a medium lengthened tail.

Tay-Sachs disease is an example of the result of incomplete dominance because the gene that makes the antibodies only creates half of the necessary antibodies which create a vulnerability in the individual to get Tay-Sachs. Similarly. Sickle cell disease is the result of incomplete dominance as those who have the disease carry 50% normal and 50% abnormal haemoglobin.

- **Multiple Allelism :** Presence of more than two alternative forms (alleles) of the gene occupying the same locus on a chromosome in the population is known as multiple alleles.
  Ex. ABO blood groups in human beings. The gene I controls the ABO blood groups. It has three allele : I^A, I^B, I^O.
  However, in all individuals only two among these alleles are present.
- **Co-dominance:** In co-dominance, the "recessive" & "dominant" traits appear together in the phenotype of hybrid organisms. In a human the ABO blood group system represents co-dominance as everyone has two copies of this gene; someone could have an A and B, AO, BO, AB or OO as listed in the table.

Blood group	Gene
A	AA, AO
B	BB, BO
AB	AB
O	OO

- **Sickle cell anaemia :** It along with incomplete dominance also exemplifies the co-dominance since both normal shapes and shapes of sickles and are seen in the blood. Other examples of co-dominance in animals include roan cattle, agouti mice and tabby cats. Red and white flowers of Camellia from a cross between the plant bearing flowers with the plant bearing red flowers are the other examples of co-dominance. Sickle cell trait is exampel of codominance. Sickle cell trait is example of codominance.

Normal red blood cell (which is shaped a bit like a doughnut) **A sickle-shaped red blood cell of sickle cell disease**

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Incomplete Dominance vs Co-dominance	
Incomplete Dominance	**Co-dominance**
The effect of one allele is more noticeable.	The effect of both alleles is equally noticeable.
A fine mixture of the expressions of both alleles.	There is no mixing of the effect of both alleles.
The effect in hybrid is in the middle or intermediate of both alleles.	Both alleles express them independently.
The expressed phenotype won't have any allele of its own.	The expressed phenotype will show the combination of both alleles and phenotypes.
An incompletely dominance has quantitative effect.	It has no quantitative effect.

Phenylketonuria (PKU) : It is a classical example of pleiotropism in humans. The disease can cause mental retardation and reduced hair and skin pigmentation. It can be caused by any of a large number of mutations in a single gene that codes for the enzyme phenylalanine hydroxylase which converts the amino acid phenylalanine to tyrosine, another amino acid. Depending on the mutation involved, conversion of phenylalanine to tyrosine is reduced or ceases entirely. Other well-known examples of pleiotropy include albinism and sickle-cell anaemia.

- **Pleotropism :** It's a phenomenon in which a single gene affects a number of phenotypic traits in the same organism. These pleiotropic effects often seem to be unrelated to one another. The usual underlying mechanism is that the same gene is activated in several different tissues, producing apparently different effects.
- **Multiple allelism :** A gene for which more than two alleles exist is said to be polymorphic. The multiple alleles occur and are maintained within a population; any individual possesses only two such alleles (at equivalent loci on homologous chromosomes).
- Two human examples of multiple-allele genes are the gene of the ABO blood group system, and the human leukocyte associated antigen (HLA) genes. The most striking feature of HLA genes is their high degree of polymorphism there may be as many as one hundred different alleles at a single locus. If an individual possesses five or more HLA loci, donor-recipient matches for organ transplantations become rare . The fewer HLA antigens the donor and recipient have in common, the greater the chance of rejection.

Chromosome theory of inheritance: Boveri–Sutton in 1902-1903 proposed chromosome theory as a fundamental unifying theory of genetics.

- identifies chromosomes as the carriers of genetic material.
- explains the mechanism underlying the laws of Mendelian inheritance proposed by Mendel.

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- states that chromosomes are linear structures with genes located at specific sites called loci along them.
- states that chromosomes present in all dividing cells , pass from one generation to the next, These are the basis for all genetic inheritance.
- **Linkage :** It refers to the tendency of alleles that are close together on a chromosome to be inherited together during the meiosis phase of sexual reproduction. Genes with loci nearer to one another are less likely to be separated into different chromatids during chromosomal crossover, and are therefore said to be genetically *linked, i.e.* the nearer two genes are on a chromosome, the lower is the chance of a swap occurring between them, and the more likely they are to be inherited together. It is an exception to Mendel's "law of independent assortment."
- **Linkage map :** Also called **genetic map,** it was first developed by Alfred Sturtevant. He proposed that the greater the distance between linked genes, the greater the chance that non-sister chromatids would cross over in the region between the genes. By working out the number of recombinants, it is possible to obtain a measure for the distance between the genes. This distance is expressed in terms of **a genetic map unit (m.u.), or a centimorgan (cM)**. It is defined as the distance between genes for which one product of meiosis in 100 is recombinant, *i.e.* a recombinant frequency (RF) of 1% is equivalent to 1 m.u. The largest percentage of recombinants cannot exceed 50%, when the two genes will be at the extreme opposite ends of the same chromosomes.
- **Types of chromosomes :** The chromosomes are the most important structures in a cell during division being the carrier of DNA. Hence, They are responsible for the transmission of the hereditary information from one generation to the next. There are two types of chromosomes. Those are autosomes and sex chromosomes. Sex chromosomes also known as 'Allosomes'. Sex chromosomes are important in sex determination.

Autosomes v/s sex chromosomes

These are two types of chromosomes present in each cell but they differ as:

- autosomes are homologus chromosomal pairs but sex chromosomes are partially homologous chromosomes.
- autosomes are responsible for somatic expression and growth but sex chromosomes are meant for sex determination at the time of the fertilization.
- in autosomes both chromosomes in pair have equal length but in sex chromosomes, Y-chromosome is shorter than X-chromosome.
- in autosomes, the position of centromere is the same but not in sex chromosomes.

- **Sex chromosomes in plants :** All dioecious species have the potential to evolve sex chromosomes, Many plants belonging to the class of bryophyta and gymnosperms show the sex determination system. Plants bearing Y-chromosomes include papaya, cucumber, asparagus, etc.

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- **Types of variations :** All sexually reproducing organisms undergo variations, *i.e.* differences in their genotype, phenotype or both. The basic causes of these variations can be crossing over, mutation, improper expression of genes, changes in response to their habitat, etc. All these variations have, therefore, been classified into two types, somatic and germinal variations.
- **Somatic v/s Germinal variations :** The variations which are not inherited are called somatic variations while the ones that are inherited by the offspring are germinal variations. The basic cause of germinal variations is the change in the genetic constitution of germ cells.
- **Mutation :** Structural and functional change in the gene is known as mutation. T.H. Morgan studied and explained mutation as a sudden inheritable change that occurs in the genotype of an organism. He worked on fruit fly (*Drosophila melanogaster*) to explain mutation. It's one of the insects with the same genetic constitution of sex chromosomes as humans, *i.e.* the female has XX and the male as a fly has XY chromosomes. The studies have revealed that mutation can be gene mutation such as in sickle cell anaemia or can be because of non-disjunction of chromosomes leading to monosomic or trisomic conditions such as in Down's syndrome, Patau's syndrome, etc.
- **Sex determination :** It is a biological system that determines the development of sexual characteristics in an organism. In many sexually reproducing species, sex determination is genetic, with males and females having different alleles or even different genes that specify their sexual morphology. It is often accompanied by chromosomal differences, generally through the combinations of XY, ZW, XO, ZO chromosomes or haplodiploidy. The sexual differentiation is generally triggered by a main gene (a "sex locus"), with a multitude of other genes following in a domino effect.
- **XX/XY sex-determination :** It is the most familiar being found in humans. In the system, females have two of the same kind of sex chromosomes (XX), while males have two distinct sex chromosomes (XY). Therefore, males are genetically responsible for the sex of an offspring.
- **XX/X0 sex determination :** It is found in species where females have two copies of the sex chromosome (XX) but males have only one (X0). The *0* denotes the absence of a second sex chromosome. Generally in this method, the sex is determined by the amount of genes expressed across the two chromosomes. This system is observed in a number of insects, including grasshoppers , crickets and in cockroaches.
- **ZW sex determination :** It is found in birds, some reptiles and some insects. The ZW sex-determination system is reversed compared to the XY system: females have two different kinds of chromosomes (ZW), and males have two of the same kind of chromosomes (ZZ). Hence, females are genetically responsible for the sex of an offspring.
- However in some reptiles including alligators, some turtles and tortoises sex is determined by the temperature at which the egg is incubated during a temperature-sensitive period.

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Turner's syndrome v/s Klinefelter's syndrome		
Character	**Turner's syndrome**	**Klinefelter's syndrome**
Genotype	44+ XO	44+ XXY
Sex	Sterile female	Sterile male
Character	Undeveloped ovaries and breasts, small uterus, absence of menstruation, absence of one X chromosome, narrow hips. Monosomy of X Chro-some.	Undeveloped testes, sparse body hair, feminine pubic hair, gynaecomastia, presence of one or more extra X chromosome, feminine pitched voice.
General features	Short stature, heavy neck muscles, narrow hips, cardiovascular abnormalities and hearing impairment	Long limbs, knock knees, mental retardation.

- **Hereditary diseases :** These disorders or diseases are inherited genetically. They are also known as genetic disorders or inherited diseases and may be passed on within the family if there is a mutant gene present.

List of Hereditary Diseases

- **Autosomal Dominant Diseases :** A person may suffer from autosomal dominant disease when it gets an abnormal gene from one parent who suffers from the same disease. When one of the parents has a mutant gene and the other has a normal gene, the child has 50% chance of inheriting the disorder. Examples of autosomal dominant diseases are the ones mentioned below.

Disease	Abnormality
Achondroplasia	Abnormally short stature with dispro-portionately short limbs. The adult may reach an average height of 4 feet. It is caused because of the mutation of the FGFR3 gene.
Down Syndrome or Trisomy of the 21st chromosome	It is caused by the inheritance of an extra chromosome 21. This condition causes delay in the mental and physical development of a child. This genetic disorder is rare and may be detected before a child is born. The affected person has round face, Palmer's crease and is sterile. Also called Mongolian idiocy
Spherocytosis	Abnormal red blood cells that may lead to haemolytic anaemia and the enlargement of the spleen (splenomegaly). RBCs became spherical shaped.

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Huntington's disease	Problems with mood or mental abilities, general lack of coordination and an unsteady gait often follow. As the disease advances, uncoordinated, jerky body movements become more apparent and finally as brain cells die, the person suffers from dementia.

➢ **Autosomal Recessive Diseases**: These genetic disorders are passed when both of the parents carry a defective gene such as in the following diseases :

Disease	Abnormality
Tay - Sachs Disease	It's a disorder of the nervous system that impairs motor skills. It caused due to non production of Hex-A enzyme. The affected child experiences symptoms such as delayed growth, dementia, irritability and even paralysis.
Usher Syndrome	It is characterized by hearing loss or deafness that may be present from the birth. The affected person may lose vision during adolescence.
Hereditary Fructose Intolerance	It is caused by the absence of enzyme aldolase B in a person,required for metabolizing fructose. Symptoms include severe abdominal pain, vomiting and aversion to sweet foods.
Albnisim	It is caused because of the absence of melanin production, the skin, hair or eyes have little or no colour. It is also associated with vision problems.
Cystic fibrosis	A defective gene causes the secretions to become thick and sticky. Instead of acting as a lubricant, the secretions plug up tubes, ducts and passageways, especially in the lungs and pancreas. It is also characterized by salty sweat.
Phenylketonuria (PKU)	Intellectual disability, delayed development, poor bone strength, skin rashes (eczema), a musty odour in the child's breath, skin or urine, caused by too much phenylalanine in the body, blue eyes, because phenylalanine cannot transform into melanin and abnormally small head.
Sickle cell anaemia	It is caused because of the gene for haemoglobin synthesis such that RBC takes up the shape of a sickle and, hence, has reduced oxygen carrying capacity.

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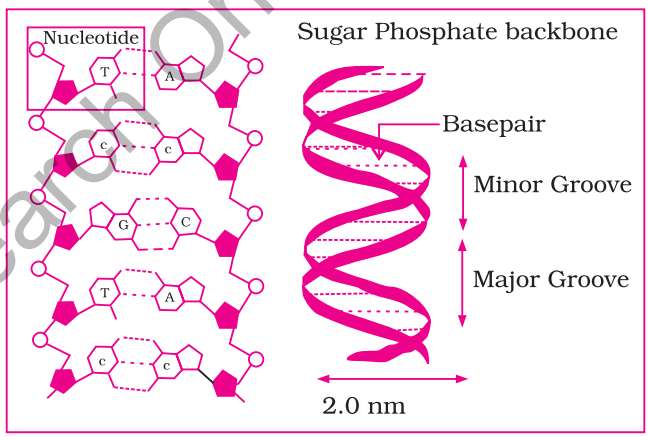
- **Sex chromosome Linked Disorders :** These disorders occur due to errors in X or Y chromosome. They include the following.

Disease	Abnormality
Colour Blindness	This is 'x'-chromosome linked disorder. This condition causes eye-nerve damage and the affected person can't differentiate between colours, particularly red and green.
Haemophilia	The disorder causes the inability of the blood to coagulate. This condition affects only males with defective gene present on Y-chromosome.
Muscular Dystrophy	It is a muscle disorder that causes weakness of the skeletal muscles, degeneration of the muscles and defective muscle proteins.

DNA structure : The features of the DNA molecule were described by Watson and Crick in 1953. According to them, DNA

- Consists of 2 chains with antiparallel orientation

  5′——————>3′ and 3′<——————5′
- a purine is always in opposite of a pyrimidine or vice versa.
- chains held together by H-bonds
- Guanine is paired with cytosine by triple H-bonds
- Adenine is paired with thymine by double H-bonds
- nucleotides comprising of phosphate group, deoxyribose sugar and nitrogenous bases are bonded together by phosphodiester bonds.



- Each turn of DNA is made up of 10.4 nucleotide pairs and the centre-to-centre distance between adjacent nucleotide pairs is 3.4 nm. The coiling of the two strands around each other creates two grooves in the double helix

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- **Properties of DNA :** DNA possesses two main properties called replication and transcription which have allowed it to act as the genetic material. These include:
- **DNA replication :** It is the biological process of producing two identical replicas of DNA from one original DNA molecule. This process occurs in all living organisms and is the basis for biological inheritance. The process involves the unzipping of two strands by enzyme helicase followed by the binding of new purine and pyrimidine at respective sites either continuously on leading strand or in the form of Okajaki segments in lagging strand. Once binding finishes, DNA ligase binds the strands together.
- **Transcription :** It is the first step of gene expression, in which a particular segment of DNA is copied into RNA (mRNA) by the enzyme RNA polymerase. During transcription, a DNA sequence is read by an RNA polymerase, which produces a complementary, anti-parallel RNA strand called a primary transcript.
- The stretch of DNA transcribed into an RNA molecule is called a *transcription unit* and encodes at least one gene.
- **Gene expression :** A gene is expressed by the virtue of the processes of transcription followed by translation as per central dogma.

$$\text{DNA} \xrightarrow{\text{Transcription}} \text{RNA} \xrightarrow{\text{Translation}} \text{Protein}$$

- **Translation :** It is the second major step in gene expression; the mRNA is "read" according to the genetic code, which relates the DNA sequence to the amino acid sequence in proteins. Each group of three bases in mRNA constitutes a codon, also called genetic code, which is universal, and each codon specifies a particular amino acid. Hence, it is a triplet code. The mRNA sequence is thus used as a template to assemble—in order—the chain of amino acids that form a protein. The most common start codon in translation is AUG which codes for methionine.
- **Nonsense codon :** Of the total of 64 codons, three codons UAA,UAG and UGA are called non-sense codon. These codons do not code for any amino acid but act as the terminator of protein synthesis during translation.
- **DNA fingerprinting :** It was invented in 1984 by Professor Sir Alec Jeffreys after he had realised that one could detect variations in human DNA, in the form of these minisatellites called VNTRS (Variable Number of Tandem Repeats). Jeffreys called these unique patterns as minisatellites.
- It detects lots of minisatellites in the genome to produce a pattern unique to an individual called DNA fingerprint.
- The probability of having two people with the same DNA fingerprint that are not identical twins is almost negligible.
- Therefore, it is used in forensic science in the detection of culprits and for resolving the issues related to maternity or fraternity.

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Chapter 9

EVOLUTION, INORGANIC AND ORGANIC EVOLUTION

Oparin theory of origin of life, Stanley Miller's and Urey's experiment, Fossils, Homologous organs, Analogous organs, vestigial organs, Theories of organic evolution: Lamarckism, Darwinism, and NeoDarwinism, Industrial melanism, Evolution of horse and Evolution of humans.

- **Evolution :** It's the branch of biological science that deals with the study of the origin of life and then the origin of different life- forms from a aggregates of precells or protobionts cell called coacervate and microspheres that had evolved some 2.5 billion years ago. The origin of life on the earth is known as 'Protobiogenesis'. Evolution as a branch of science has broadly been classified into two , the inorganic evolution and organic evolution.
- **Origin of Universe :** Big-Bang theory proposed by Abbe Lemaitre in 1931 well explained the origin of the universe some 15 billion years ago. According to the same theory, the earth evolved in the universe some 4.6 billion years ago.
- **Origin of life :** It deals with the inorganic evolution, *i.e.* the origin of life as the first living cell on primitive earth some 2.5 billion years ago. Many scientists did try to explain the origin of life but the best explanation was proposed by A. I. Oparin and J. B. S. Haldane in their proposals explaining the origin of life. The validity of their proposals increased appreciably when Stanley Miller in 1953 developed the simple but complex sugar molecules and amino acids using the same constituents present in primitive earth atmosphere.
- **Constituents of the primitive earth's atmosphere :** The primitive earth's atmosphere was not like today's atmosphere. It was reducing in nature with high temperature conditions. The primitive reducing atmosphere contained methane, ammonia, hydrogen and water vapour. It was from these constituents only that Miller had produced sugar and amino acids in a discharge tube after their exposure to high temperature conditions (800^{0}C).

Oparin and Haldanes theory of origin of life : In 1924, Oparin, a Russian biochemist and Haldane working independently, put forth the influential theory that life on the Earth developed through gradual chemical evolution of carbon-based molecules in a "primordial soup." They asserted that :

- There is no fundamental difference between a living organism and lifeless matter.
- The infant Earth had possessed a strongly reducing atmosphere, containing methane, ammonia, hydrogen and water vapour, which were the raw materials for the evolution of life.

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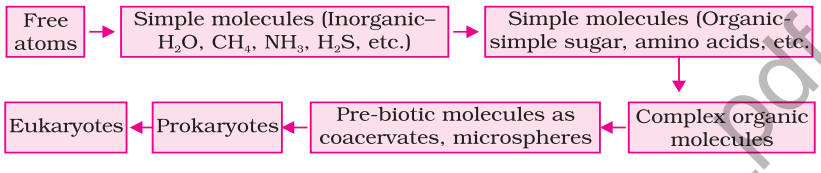
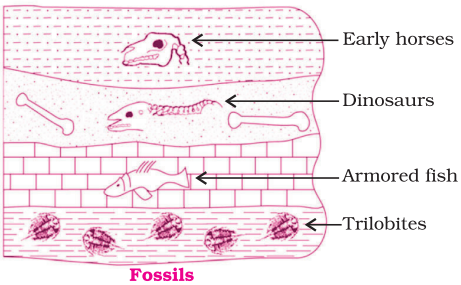
- As the molecules grew and increased in complexity, new properties came into being and a new colloidal-chemical order was imposed on the simpler organic chemicals determined by the spatial arrangement and mutual relationship of the molecules leading to the origin of the first living cell type called coacervates, and later in living matter.

Modern theory of origin of life : The theory can well be summarized as :



- **Theory of special creation :** It was the sum of many theories proposed by ancient philosophers to explain the origin of life. These theories laid emphasis on the supernatural powers or gods for the creation of different forms of life. They believed that all living organisms that we see today were created as such some 4000 years ago only.
- **Miller–Urey experiment :** In 1953 Stanley Miller, with assistance from Harold Urey, at the University of Chicago, carried out a chemical experiment that simulated the conditions (to be present on the early Earth) to test the chemical origin of life under those conditions. The experiment confirmed Alexander Oparin's and J. B. S. Haldane's hypothesis that putative conditions on the primitive Earth favoured chemical reactions that synthesized more complex organic compounds from simpler inorganic precursors leading to the origin of life.
- **Organic evolution :** The organic evolution can be defined as a slow, gradual, continuous and irreversible changes which are responsible for present day complex forms developed from pre-existing simple forms in the past.
- **Evidences in favour of organic evolution :** Presently, there are a number of evidences available to support the concept of organic evolution and origin of a species from the pre existing species. Some of these evidences include :
- **Fossils :** These are the dead remains or the impressions of the organisms mostly found in sedimentary rocks in various geological layers which had inhabited the earth in its primitive past.



Fossils

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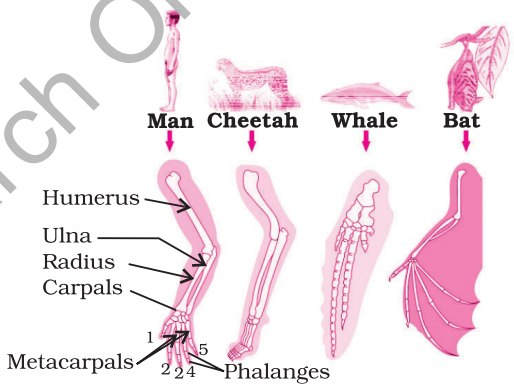
The study of these fossils called palaentology which not only provides the information about their structures but also help link to the origin of a species from another species such as the fossil of a flying dinosaur (Archaeopteryx) helped link the origin of birds from reptiles. The fossil bird had characters of both birds and reptiles like beaks with teeth and wings with claws along with long but pneumatic (hollow) bones.

- **Vestigial organs :** These are organs which though present in an organism, are functionless. They only interlink the line of evolutionary development. The presence of appendix, third molar , ear muscles, nictitating membrane in humans are some of the vestigial organs. These organs in other lower mammals or animals have their own specific functions like appendix in ruminants, ear muscles in animals which need to move their ears to fan the body for cooling, etc.

However, there are some organisms which are still living but exhibit the characters of two different species. These are called living fossils such as scorpions, egg–laying mammals like platypus or recently discovered fish latemera in animals and Cycas in plants.

- **Atavism :** It is the condition in which the ancestral characters develop in an organism such as in humans. Sometimes a baby is born with a small tail or has long hair or skin or extra mamme (breasts)

Homologous organs : These are organs present in different species of organisms which have common origin with similar structure but are different in functions such as:



Homologous Organ

- forelimbs of a frog, lizard, bird, horse, bat and human
- mouth parts of insects
- thorn of *Bougainvillea* and *Curcubita*
- leaf tendrils of *Pea* and leaf spines of *Barberry*

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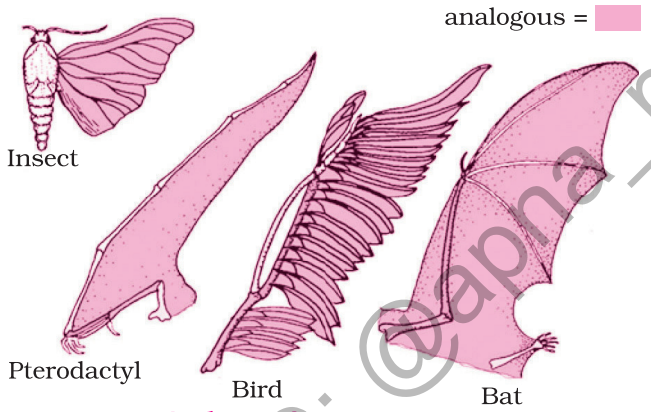
Structural homology : The structural homology has also been observed in the development of the different body organs such as the development of four-chambered hearts in mammals, two-chambered venous hearts in fish or the development of a simple small-size brain or complex brain in a human.

Analogous organs : These are organs present in different species of organisms which have similar function but are different in their origin and structure such as.



Analogous Organ

- sting of a scorpion and honeybee
- wings of a bird and butterfly
- wings of a bird and bat
- fins of fish and flippers of whales
- tendrils in Pea and Lathyrus.
- **Convergent evolution :** It refers to the development of similar adaptive functional structures in organisms belonging to different species. It is well exemplified by the organisms showing analogous similarity such as the wings of a butterfly, bird and bat.
- **Divergent evolution :** It refers to development of different adaptive functional structures from a common ancestral form. It is well exemplified by the forelimbs helping in the different modes of locomotion despite having common origin in the different classes of animals.
- **Theory of acquired characters :** J. B. Lamarck(1744–1829) had proposed the theory of acquired characters based on the use and disuse of organs. He stated that an organism can pass on characteristics that it has acquired during its lifetime to its offspring, *i.e.* Inheritance of acquired characteristics or soft inheritance. Lamarck originated the idea of soft inheritance, which proposes that individual efforts during the lifetime of the organisms were the main mechanism driving species to adaptation, as they supposedly would acquire adaptive changes and pass them on to offspring.

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He suggested the above with examples of the evolution of a long-neck giraffe and of limbless snakes from their predecessors. But later, his theory was discarded by Wisemann's Theory of Continuity.

- **Theory of origin of species by natural selection :** Charles Darwin, a naturalist during his voyage around the world, happened to be inspired by his study of the finches at Galapagos islands and later by Wallaces theory on population. He proposed his views explaining the origin of a species from the existing species in his book entitled "Origin of Species by Natural Selection". Darwin's scientific discovery is the unifying theory of the life sciences, explaining the diversity of life.

His theory was based on :

- **Over-reproduction (or Enormous fertility or Prodigality of production) :** All organisms irrespective of their types, tend to over-reproduce to maintain the continuity of their species.
- **Struggle for existence :** With increased number of individuals produced, as the resources remain the same and limited while the needs increased, the competition develops to meet the needs necessary for survival. The struggle may be (i) Intra-specific (ii) Inter-specific (iii) Environmental.
- **Survival of the fittest (or Natural selection) :** In the struggle for existence, only those manage to survive who prove themselves the fittest. Hence, the fittest survive while the rest perish. The nature selects the organisms which are provided with favourable variations. Hence, it is also knows as natural selection. With this ongoing struggle and the selection of the fittest, the origin of new species takes place over millions of years.

Darwin developed his idea of natural selection during the course of his voyage on H.M.S. Beagle(1831-1836) when he closely watched and studied the finches (species of passerine birds) at Galapagos islands, close to northern west part of South America.

- **Neo-Darwinism :** Neo-Darwinism, the modern version of Charles Darwin's theory of evolution by natural selection, incorporates the laws of Mendelian genetics and emphasizes the role of natural selection as the main force of evolutionary change. The term *neo-Darwinism* was first used in the 1880s by August Weismann, a German naturalist, who incorporated his theory of the germ plasm into Darwin's theory of evolution by natural selection.
- **Theory of mutation :** T.H. Morgan did not nullify the Darwin's theory of Natural selection but argued that the natural selection is too slow for such diversity of life to evolve and exist on the earth. He proposed his theory based on mutation, the sudden inheritable

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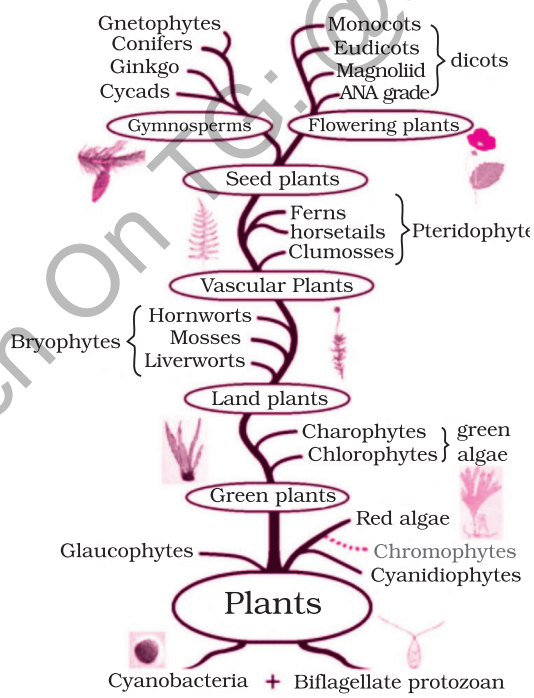
changes that occur mostly in sexually reproducing organisms in which prior to gamete formation crossing over of the genetic material takes place for variations to appear.

- **Biogenetic law (Recapitulation law) :** It was proposed by Ernst Haeckel as 'Ontogeny recapitulates phylogeny', *i.e.* all organisms during the course of their embryonic development pass through all the stages of evolutionary development. The species has undergone to which it belongs such as the stage of a tadpole in the life-cycle of a frog or bearing of a tail by a human foetus during prenatal stage. All these changes also favour the fact that organic evolution has occurred and is occurring from simple to complex.
- **Industrial melanism and Natural selection :** Industrial melanism refers to the evolution of dark body colours in animal species that live in habitats blackened by industrial soot. e.g. the black coloured peppered moths survived after the industrial revolution. The phenomenon has been documented in numerous species that hide from predators by blending in with their backgrounds, *i.e.* camouflage. It is one of the best example of natural selection.



Evolutionary Tree of Plant Kingdom

Peppered moths : Before the industrial revolution, peppered moths in the UK were predominantly pale grey coloured. Their habitat was lichen covered oak trees but after their habitats had become polluted

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with soot from coal-fired industries, they fell pray to the predatory birds and their number decreased on the other hand melanic (black) phenotypes became numerous and spread to other regions. Away from industrial centres, the pale phenotype remained common.

The melanic and pale phenotypes are determined by genes, and the changes in their percentages in populations reflect natural selection. Experiments identify bird predation on the moth phenotypes as the agent of selection. This leads to conclude that:

- The natural colour patterns of animals are adaptations produced by natural selection.
- Mutations introduce new genetic variation to a population,
- Random changes in the frequency of genes (genetic drift) are irregular and unpredictable in direction.
- Directional, rapid changes in the frequency of genetically determined phenotypes in populations result from natural selection.
- Gene flow (migration) retards genetic differentiation among geographically widespread populations.
- Parallel evolution is 'Nature's replicate experiment'

Evolution and time scale : The evolution has taken over millions of years. Therefore, a varied time scale is used for describing the time of the origin of a phylum, class in animals or division in plants as given below.

EON	ERA	Period	Millions of years AGO
Phaneroznoic	Cenozoic	Quaternary	5 to present
		Tertary	60–5
	Mesozoic	Cretaceous	125–60
		Jurassic	160–125
		Triassic	195–160
	Palaeozoic	Permian	220–195
		Carboniferons	305–220
		Devonian	355–305
		Silurian	395–355
		Ordovician	480–395
		Cambrian	540–480
Proterozoic	Proteozoic ---	Pre Cambrian	1500–550
Arechean	Archaeozoic ---- -----	Chaean	2700–1500
	PRE-Archean		3800

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Stages in evolution of horse

S.N.	Name	Period	Characteristics
1.	**Modern horse**	1million years ago	1.6m tall, front legs long and hind legs muscular and strong giving the horse great power, speed and endurance. Neck muscular and strong allowing Equus to balance and easily reach for forage.
2.	**Dinohippus**	1.5 million years ago	1.25m tall, forelimbs and hindlimbs are strong with the single toe now a hoof. Body has become sturdy and powerful. Neck powerful and muscular.
3.	**Pliohippus**	10 million years ago	1.0m tall, Front and hind legs, one single toe that becomes the hoof. Body strong and solid, looking much like the modern horse. Neck strong and more slender to balance and easily reach for forage.
4.	**Merrychippus (Ruminant Horse)**	20 to 11 million years ago	1.0m tall. Front legs and longer hind able to stand on one central toe with the side toes partly functioning. Increased neck length. Body became heavy.
5.	**Mesohippus**	30 million years ago	0.6m tall , Front forefeet long legs, hind feet long legs with three toes on the front and hind legs. Neck long in length, back longer with less upward arching.
6.	**Eiohippus (Dawn horse)**	60 million years ago	0.4m tall, forefeet and hind feet had pads similar to those found on a dog with no hooves, Four toes on the front feet. Three toes on the hind feet, Short neck with poly dentition like humans.

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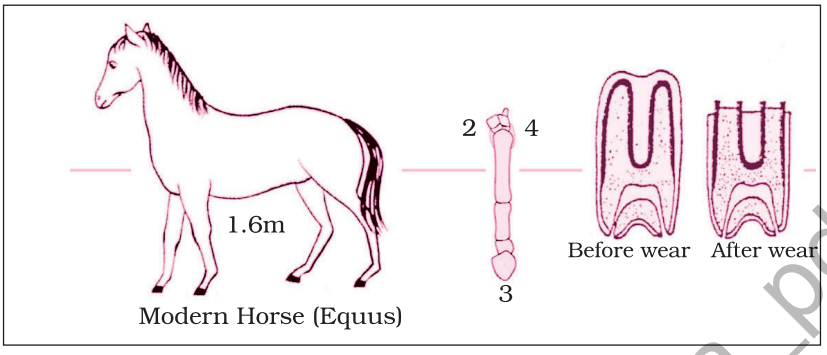
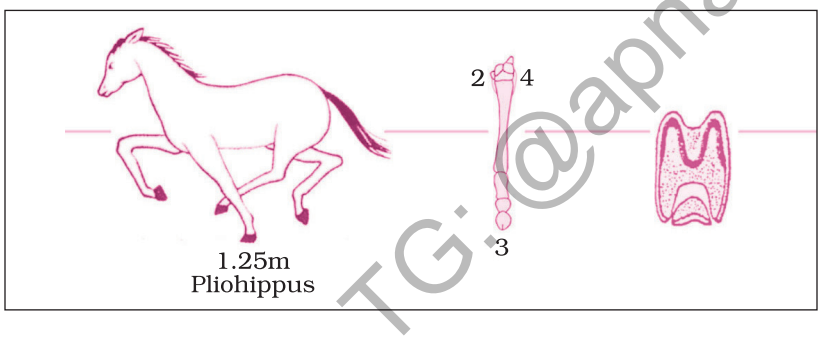
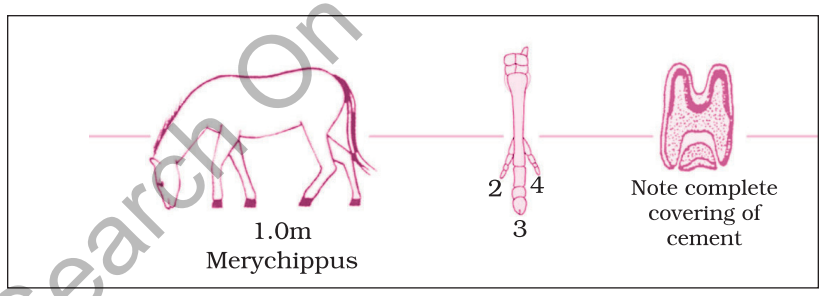
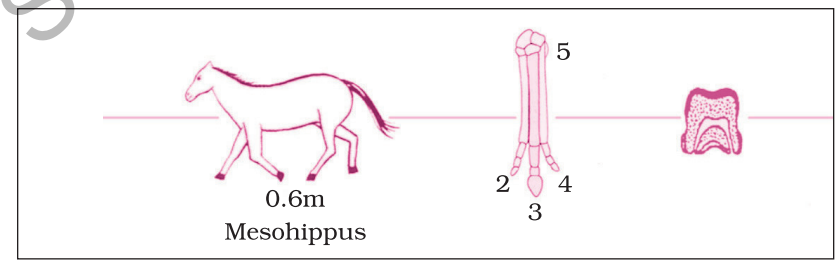
Whole Animal (Height)	Forefeet	Molar teeth









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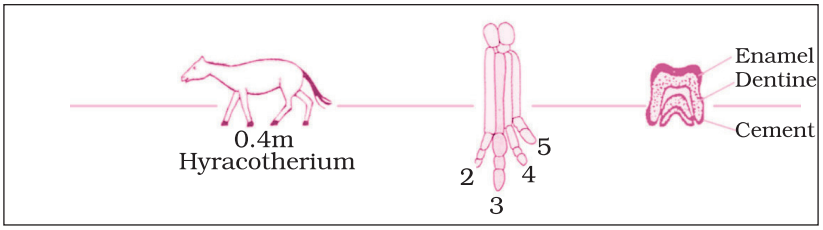

Evolution of a horse

Stages in evolution of modern man			
S.N.	**Name**	**Period**	**Characteristics**
1.	**Homo sapiens sapiens**	40,000 years ago	1.6m tall, very wise and thinking excellent hunter, sophisticated weapons, control over environment. spread to North America and Australia first to develop art (*Cave paintings and Venus figures*).
2.	**Homo sapiens:** *(sapiens = thinking)*	2 lakh - 1 lakh years ago, Southern Africa	1.25m tall, humans with appearance very similar to a modern human, high forehead encasing a large brain, lower jaw with chin and the earliest Homo sapiens were Neanderthals
3.	**Homo erectus:** ...	1 million to 2.5 lakh years ago.	Upright human, protruding jaw, no chin, thick brow ridges and a long skull, teeth smaller than in habilis, much larger brain than habilis (1000 CC), advanced speech, controlled fire and made more sophisticated tools than predecessors. Left Africa and spread throughout Asia and Europe
4.	**Homo habilis:** *(homo:human; habilis = using* hands)	2- 1.5 million years ago.	Handy human; with most of the man lkie characters evidence of the manufacture of stone tools, face still primitive, brain one half the size of a modern human, rudimentary speech, may have built first shelters.

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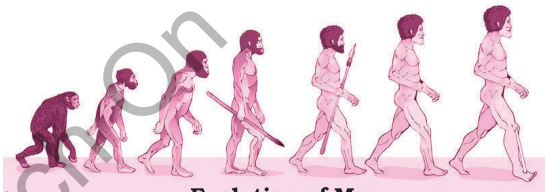
5.	**Australopi-thecus** (Australo: South, pithecus: Ape)	4-1.8 million years ago	Possessed a small skull, ape like features, low forehead, flat nose, no chin but jutting jaws with massive teeth. Brain was one third that of modern humans, 1.1 m tall and weighed 30 kg, had great muscular strength, lacked the power of speech. Walked slightly bow-legged. Chimpa-nzee-like hips and curved toes. Family groups would have foraged for plant foods including tough, hard or fibrous fruits and seeds. Individuals might have used crude tools of wood and stone to scavenge meat.
6.	**Ramapithecus:** *(pithecus = ape)*	14-8 million years ago	Most ancient human ancestor, a small ape-like primate (14 kg), probably walked upright. The fossils were found in Siwalik Hills of Himalaya. So, it was named as Ramapi-thecus.



Evolution of Man

THE STAGES OF HUMAN EVOLUTION			
Prosimians	65 million years ago	Monkeys	40 million years ago
Prehistoric apes	30-20 million years ago	Modern apes	7-4 million years ago

- Common ancestor of apes and humans **:** Dryopithecus
- Australopithecus robustus : (robustus = strong) (2 - 1.5 M.Y.A.), the ultimate chewing machine. Average life span was 17 years.
- Australopithecus boisei : (1.8 M.Y.A.) nut-cracker human, with a structure resembling the gorilla.

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Chapter 10

BIOTECHNOLOGY PRINCIPLES AND APPLICATIONS

Biotechnology and endonucleases, PCR, development of rDNA, development of GM crops such as Bt.cotton, application of biotechnology in frutification of agronomic products and development of drugs.

Biotechnology : It is the use of living systems and organisms to develop or make products, or "any technological application" that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use.

Conventional biotechnology v/s modern biotechnology: Biotechnology is a process of using microorganisms or any other biological agent to make different products required by mankind. Conventional biotechnology used microorganisms for the production of alcohol, acetic acid, foodstuffs like curd, yoghurt, cheese, etc. The people were not even aware of the enzymes and their role in production processes but modern biotechnology involves the use of genes or development of recombinant DNA to obtain the same product at faster rate with minimal side-effects, if any.

BIOLOGY

Conventionally used micro-organisms			
Micro-organism	**Product**	**Micro-organism**	**Product**
Streptococcus Thermophillus	Yoghurt	*Aspergilluss wentii*	Tempe
Lactobacillus	Cheese	*Aspergilluss soyae*	Soy sauce
bulgaricus			
Lactobacillus lactis	Curd	*Saccharomyces cerevisae*	Alcohol
Rhizopus stolonifer	Butter	*Acetobacter aceti*	Acetic acid

Exonucleases v/s endonucleases:

Endonucleases are nuclease enzymes which catalyze the hydrolysis of single nucleotides present in a chain of DNA. Nucleases play a vital role in analyzing the sequence of nucleotides in DNA and RNA.

Exonuclease enzymes are a category of enzymes that cleave the nucleotides at the ends of the DNA molecule. A good example of a group "a" exonuclease enzyme is the venom of a rattlesnake and of russell viper. This venom hydrolyzes all the 3' bonds in DNA or RNA liberating the nucleotides units as nucleoside 5' phosphates.

The class "b" enzymes are represented by the spleen's phosphodiesterase which hydrolyzes all the "b" or 5' linkages of both DNA and RNA and thus liberates only nucleoside 3' phosphates.

Endonucleases considered as molecular scissors are enzymes that cleave to the bonds of the DNA from within the molecule. They do not require a free 3' or 5' hydroxyl group at the end of the polynucleotide chain. The endonucleases attack specific 3' or 5' linkages in the polynucleotide chain.

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Restriction endonucleases : These are enzymes used for cutting DNA at a specific site having pallindromic sequence. Therefore , they are also called as specific molecular scissors. A restriction enzyme recognizes and cuts DNA only at a particular sequence of nucleotides. For example, the bacterium *Hemophilus aegypticus* produces an enzyme named HaeIII that cuts DNA wherever it encounters the sequence

5'GGCC3' 3'CCGG5'.

The cut is made between the adjacent G and C.These enzymes are used for separating a gene from a DNA strand after its isolation to develop recombinant DNA (DNA strand with an alien gene).

Extraction of DNA : There are three basic steps in a DNA extraction :

- Collection of cells followed by the breaking of their membranes open to expose the DNA along with the cytoplasm within (cell lysis). Lipids from the cell membrane and the nucleus are broken down with detergents and surfactants and proteins by adding a protease and RNA by adding an RNase.
- The solution after being treated with concentrated salt solution to make debris such as broken proteins, lipids and RNA to clump together is centrifuged for the separation of DNA in ice cold ethanol or isopropanol. DNA is insoluble in these alcohols and, therefore, aggregates together, giving a *pellet* upon centrifugation. Precipitation of DNA is improved by the increasing of ionic strength, usually by adding sodium acetate (HCOONa).

Cellular and histone proteins bound to the DNA are removed either by adding a protease or by having precipitated the proteins with sodium or ammonium acetate. After isolation, the DNA is dissolved in slightly alkaline buffer, usually in the TE buffer, or in ultra-pure water.

Detection of DNA in a cell : A diphenylamine (DPA) indicator confirms the presence of DNA. The procedure involves the chemical hydrolysis of DNA in acid at 95^{0}C in the presence of deoxyribose sugar. In the reaction 2-deoxyribose is converted to 3-hydroxylevulinyl aldehyde, which reacts with the compound, diphenylamine, to produce a blue-coloured compound. DNA concentration is determined by measuring the intensity of the absorbance of the solution at 600 nm with a spectrophotometer. DNA absorbs UV light at 260 and 280 nm.

Polymerase Chain Reaction (PCR) : It is an easy and cheap tool to amplify a focused segment of DNA, useful in the diagnosis and monitoring of genetic diseases, identification of criminals (DNA fingerprinting), studying the function of targeted segment, etc. PCR completes in three steps :

The first step is the denaturation step in which the hydrogen bonds holding the complementary strands of DNA together are broken.

- The second step is the annealing step. In this step, the primers anneal or attach to the DNA template.
- The third step is extension or elongation step in which DNA polymerase synthesizes a new DNA strand complementary to the DNA template strand. The extension time depends both on the DNA polymerase used and on the length of the DNA fragment to amplify. Normally, the DNA polymerase polymerizes a thousand bases per minute under optimum conditions.

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Gel electrophoresis : It is a laboratory method used for separating DNA fragments according to their sizes. In the process

- DNA samples are loaded into wells at one end of a agarose gel, and an electric current is applied to pull them through the gel.
- DNA fragments being negatively charged move towards the positive electrode. Because all DNA fragments have the same amount of charge per mass, small fragments move through the gel faster than large ones.
- Later, gel is stained with a DNA-binding dye such as ethidium bromide, the DNA fragments can be seen as bands in UV light, each representing a group of same-sized DNA fragments.
- **Cloning vectors used in biotechnology :** Clones are DNA molecules that can carry a foreign DNA segment and replicate in the host cell. These include plasmids like pBR322, bacteriophages, bacterial artificial chromosome(BAC) or yeast artificial chromosome(YAC), transpoons, etc.
- **Genetically modified crops** (**GMCs**, **GM crops**, or **biotech crops**): These are plants used in agriculture, the DNA of which has been modified using genetic engineering techniques. In most cases, the aim is to introduce a new trait to the plant which does not occur naturally in the species. Examples in food crops include resistance to certain pests, diseases or environmental conditions, reduction of spoilage or resistance to chemical treatments (e.g. resistance to a herbicide), or improving the nutrient profile of the crop. Examples in non-food crops include production of pharmaceutical agents, bio-fuels and other industrially useful goods, as well as for bioremediation. Some of the commonly genetically modified crops produced are :
- **Bt. Cotton and Bt. Brinjal :** Resistance to pests and pesticides.
- **Golden Rice :** Resistant to floods and rich in vitamin A
- **Sugar beets :** Faster growth and resistant to weeds.
- **Cassava :** Virus-and pest-resistant
- **Potatoes :** Higher starch-content along with some protein.
- **Corns :** High sugar(fructose) content.
- **Flavr Savr, Tomatoes :** Longer shelf life as they do not rot quickly.
- **Oils :** Cotton seed oil, corn oil and soya oil are mostly genetically modified and produced in the US, India and China. However, the best healthy oil for cooking is organic grapeseed oil and the best cold-pressed oil for salad dressing is olive oil.
- **Poplar trees :** Phytoremediation, *i.e.* removal of heavy metals from soil.
- **Tobaccco plants :** Pest-resistant, particularly the nematode *Melooidegyne incognitia.* to the plant roots.
- **Brassica napus :** A mustard crop with oil rich in anticoagulant heparin.
- **Triticale :** A wheat grown for higher production. It contain the genes of wheat and rye.

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List of transgenic animals		
S.N.	**Transgenic animal**	**Uses**
1.	Pig	Organ transplantation with minimal chance of tissue rejection, hence, pigs are also considered as the stores of body spare parts.
2.	Cow, Sheep and goats	Human protein in milk particularly the milk of cow called Roise
3.	Rabbits	Molecular or gene farming
4.	Mouse	Oncological studies for finding the causes and treatment of cancer.
5.	Fish: Cat fish, salmon, Common carp and gold fish	Source of human growth hormone. Increased protein-content with size almost double.

Biotechnology and industrial products : There are a number of industrial products which have been produced in larger quantity with higher purity using biotechnological applications such as

- Production of single-cell proteins (SCP) used as supplement in cattle feed.
- Production of bio-fuels from wood and sugarcane bagasse
- Increasing the effectivity of enzymes such as trypsin, lysozyme, , etc.
- Production of enzymes like prtoeases, lipases, etc.
- Production of Brazzein, Low-calorie sweetener about 2,000 times sweeter than sugar.
- Production of aniobiotics like penicillin, streptomycin,mitomycin, erythromycin, cycloheximide, etc.

Humalin to replace insulin, Reo Pro for the prevention of blood clot formation, Tissue plasmogen activator (t-PA) for protection against myocardial infraction in heart, Hepatitis Vaccine for Hepatitis-B, Interferon –alpha for Hepatitis–C and Hirudin as anticoagulant.

- **Bioreactors :** These are large tanks where the genetically important products are produced in large quantities for commercial purposes.
- **Chimaeric gene :** In rDNA technology, it's a gene constructed by combining coding sequence from one gene with the regulatory sequence of the other gene.
- **Gene therapy :** Gene therapy is the mode of the treatment of a patient with a defective gene by substituting the defective gene with normal gene. The adopted gene therapy can be embryo therapy or patient therapy. Patient gene therapy includes: ADA (Adenosine deaminase deficiency)therapy, Cancer gene therapy, SCID(Severe combined Immuno Deficiency syndrome) gene therapy.
- **ELISA :** It comes under molecular diagnosis. ELISA stands for Enzyme Linked Immunosorbent Assay test based on antigen-antibody interaction. It is widely used for the diagnosis of AIDS in a healthy normal looking person. The assay test involves the use of PCR to develop a number of molecular copies of DNA.

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Chapter 11

HUMAN HEALTH, DISEASES AND TREATMENT

Diseases and their types hereditary diseases, deficiency diseases caused by minerals and vitamins, infectious diseases caused by viruses, bacteria, fungi, protozoa and worms, immunity, methods of diagnosis.

BIOLOGY

- **Micro-organisms :** These are living organisms that can only be seen using a microscope. Examples of micro-organisms are bacteria fungi and viruses.
- **Disease :** A disease which means not at ease is a particular abnormal condition, a disorder of a structure or function, that affects part or all of an organism. The study of disease is called pathology. It is often construed as a medical condition associated with specific symptoms and signs. It may be caused by external factors such as pathogens, or it may be caused by internal dysfunctions particularly of the immune system such as SCID or a hypersensitivity including allergies and auto-immunity or an immuno-deficiency.
- **Definition of Health :** (Acc. to WHO) Health is a state of complete physical, mental and social well-being and not merely the absence of disease of infirmity.
- **Pathogen :** The disease causing micro-organism is called as pathogen.

Diseases

- Non-infectious
  - Hereditary
  - Acquired
- Infectious
  - Viral
  - Bacterial
  - Protozoan
  - Helminthic
  - Fungal

- **Bacterial cause of infection :** Bacteria can cause illness in several ways. Some are as follows :
  - destroy tissue directly.
  - become so numerous that the body fails to work normally.
  - produce toxins (poisons) that kill cells.
- **Causes of bacterial infections :** Bacteria are among the most numerous forms of life on the Earth.
  Different bacteria spread in different ways such as through
  - contaminated water (cholera and typhoid fever)
  - contaminated food (botulism, *E coli* food poisoning, salmonella food poisoning)
  - sexual contact (syphilis, gonorrhoea, chlamydia)
  - air, when the infected people sneeze or cough (tuberculosis)
  - contact with animals (anthrax, cat-scratch disease)
  - migration from one part of the body, where they are harmless, to another part, where they cause illness (as when *E coli* spreads from the intestines to the urinary tract).

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- **Exotoxins v/s Endotoxins :** Exotoxins are poisons released by live bacteria while endotoxins are poisons released when bacteria die.
- **Treatment of bacterial infections :** Most bacterial infections are cured by antibiotic drugs. These drugs either kill bacteria or prevent them from reproducing. Penicillin, the first antibiotic, is still used for treating some infections.Other widely used antibiotics include amoxicillin, bacitracin, erythromycin, cephalosporins, fluroquinolones, and tetracycline. Sometimes antitoxins are also given to counter the effects of bacterial toxins, as in the case of tetanus or botulism.

List of some common bacterial infections

Disease	Pathogen	Area affected	Modetransmission	Main Symptoms.
Botulinum	*Clostridium botulinum*	Nerves	Improperly preserved food	Diarrhoea, vomitting, double vision.
Cholera	*Vibrio cholreae*	Intestine	Contaminated water	
Typhoid	*Samonella typhi*	Intestine	Contaminated water and food	Intermittent fever, profuse sweating, gastreonteritis, rash.
Dental caries	*Streptococcus mutans/salivarius/ sanguis*	Teeth	Foul air carrying bacteria in mouth	Toothache, oral abscess, pits or holes in teeth.
Gonorrhoea	*Neisseria gonorrhoeae*	Female-Vagina, fallopian tube Male- Urethra,	Physical contact of genital organs	Painfull urination, yellowish vaginal discharge etc.
Lyme disease	*Borrelia burgdorferi*	Skin, joints, heart	Tick bite	Flue like, erythema, stiffness of neck, meningitis.
Rocky Moutain Spotted Fever	*Rickettsia rickettsii*	Blood, skin	Tick bite	High fever, chills, severe headaches and muscleaches, Insomnia etc.
Food poisoning	*Salmonella sp.*	Intestine	Contaminated food and water	Abdominal cramps, vomitting, diarrhea, nausea, fatigue.

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Strep throat	*Streptococcus pyogenes*	Skin, Upper respiratory tract	Coughing, sneezing or direct physical cpmtact	Inflamed red oral cavity and throat, swelling of tonsils.
Tetanus	*Clostridium tetani*	Nerves at synapse	Open wounds in contact of cow-dung	Fever, spasim of musles of jaw and face, pain.
Tuberculosis	*Mycobacterium tuberculie*	Lungs, bones	Air-borne by coughing/sneezing	Cough, fever, chills, night sweats evening rise of temperature.
Meningitis *(bacterial)*	*Neisseria meningitidis*	Nerves and spinal cord	Respiratory and throat secretions	High fever with chills, headache, rigidity of neck, nausea and vomitting, photophobia.
Diphtheria	*Corynebacterium diptheriae*	Upper respiratory tract,tonsils, C.N.S and heart	Respiratory and throat secretions (droplet infection)	*Difficulty in breathing, sour throat,* hoarseness and whooping sound.
Leprosy, (Hansen's diseasse)	*Mycobacterium leprae*	Nerves, skin, Granulomatous disease, ulcers, nodules, scab deformities of fingers and toes	Direct contact with open wound, prolonged contact	Leasion, loss of sensation, disfigurement of the extremities and nerve damage etc.
Pertussis, (Whooping cough)	*Bordetella pertussis*	Respiratory tract and mucous membrane	Respiratory and throat secretions, coughing/sneezing	Whooping in coughing, convulsions, shortness of breath.
Pneumonia	*Diplococcus pneumoniae* (Streptococeus phenmoniae)	Respiratory system	Respiratory and throat secretions, coughing/sneezing	Fever, chills, cough, shortness of breath.
Shigellosis, (Bacillary dysentery)	*Shigella sp.*	Intestines	Contaminated food and water.	Abdominal cramps, mild fever, frequent stool with bloody mucus, painful stool.

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List of some common bacterial infections by animals

Disease	Pathogen	Transmission	Symptoms
Anthrax	*Bacillus anthracis*	By contact with farm animal's hair, hides or excrement. through anthrax spores	In man, the disease attacks either the lungs, causing pneumonia (wool sorter's disease), or the skin, producing severe ulceration (malignant pustule)
Brucellosis	*Brucella suis* *Brucella abortus* *Brucella melitensis*	By direct contact or untreated/ contaminated milk of animals contact with the infected animals	Abdominal pain, back pain, chills, excessive sweating, fatigue, fever, headache, joint pain, loss of appetite, weakness, weight loss
Cat-scratch disease	*Bartonella henselae*	Bite or scratch of an infected cat. Contact with a cat's saliva on broken skin or the white of the eye.	Tender regional lymph-adenopathy, slight fever, headache, chills, malaise, abdominal pain, backache, convulsions or sterile suppurative papules at the site of inoculation
Cellulitis	*A Streptococcus and Staphylococcus group*	It may infect after any event that causes a break in the skin, such as : surgery, a new tattoo or piercing.	At first, the infected area will be warm, red, swollen and tender. If the infection spreads, you may have a fever, chills, and swollen lymph nodes.
Plague	*Yersinia (Pasteurella) pestis*	By rats and other rodents. Vector is a flea, Xenopsylla cheopsis which feeds on infected rodents and may bite man.	Inflammation of the lymphatics, subcutaneous tissues and viscera, diffused haemorrhage into the skin.
Epidemic typhus (Jail/ camp fever)	*Rickettisa prowazekii,*	Bite of louse	Louse–borne bacteria, hence lesions on body parts after itching at points of a louse-bite.

Viruses and Human Infections

- **Types of Viruses :** Viruses are the subcellulars that are considered to be lying at the border line of the living and the non-living. In general, viruses have a core of DNA as genetic material invested with a protein layer called capsid. They are inactive without host. However, viruses have also been classified such as:

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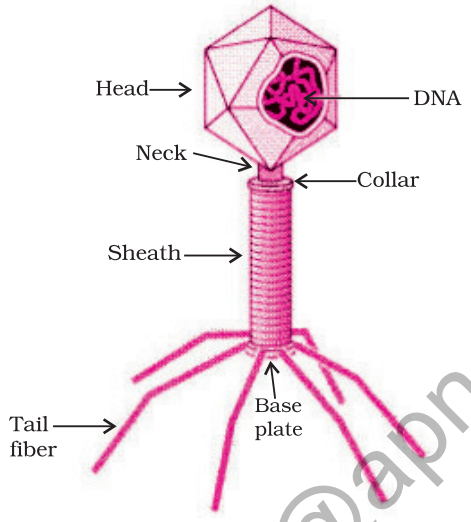
- **Bacteriophages :** These are viruses that are capable of infecting bacteria such as T-4 bacteriophage can infect bacteria *E.coli.*



- **Retroviruses :** These are viruses which have RNA as genetic material instead of DNA. Therefore, prior to their division, they undergo reverse transcription to form DNA first. Polio virus and HIV virus are the types of retroviruses.

Viruses cannot exist on their own and for survival they need to spread to another host. This is because the original host may either die or eliminate the infection. Some important routes of viral transfer include.

Route of infection	Example
Respiratory	Common Cold virus, influenza, measles, mumps, rubella
Faecal-oral	Polio, echo, Coxsackie, Hepatitis A, Rotavirus
Milk	HIV, HTLV-1, CMV
Transplacental	Rubella, CMV, HIV
Sexually	Herpes 1 and 2, HIV, HPV, Hepatitis B
Insect vector	Yellow fever, Dengue fever
Animal bite	Rabies CMV- Cytomegalovirus, HPV- Human Papilloma virus

- In addition, in order to spread, viruses need to withstand the immune system. A special category of viruses cause disease only when the immune system is deficient in some way; these are called opportunists, and opportunistic infection is one of the main problems in patients with, for example, AIDS.

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Viruses and their reservoirs	
Virus	**Animal reservoir**
Influenza	Birds, pigs, horses
Rabies	Bats, dogs, foxes
Lassa and Hanta viruses	Rodents
Ebola and marburg viruses	Monkeys
HIV-1 and -2	Chimpanzees, monkeys
Newcastle disease	Poultry
West Nile virus	Birds

Common viral infections in humans			
Disease	**Causative agent**	**Mode of transmission**	**Symptoms**
Influenza	*Myxovirus in fluenzae*	Droplet inhalation direct contact	Fever, sore throat, rhinitis (watering nose), cold, sneezing, complication may lead to pneumonia or bronchitis.
Chicken pox (Varicella)	*Varicella zooster*	Through air, touch	Slight fever with rashes which undergo change from vesicles to postules and then dark brown scabs which fall off.
Measles	*Rubeola virus*	Air borne, food, water, touch	Fever, inflammation of air passage and rashes all over the body, watering of both nose and eyes.
Mumps Polio mylelitis (Infantile paralysis)	*Paramyxo virus Enterovirus or Polio virus*	Droplet (breathing) close contact Faeco-oral route	Swelling of parotid glands leading to pain while peaking or chewing food. High fever, stiffness of neck, chilliness, body pain, If not treated timely, it leads to paralysis of limbs with infection reaching C.N.S.
Viral **Hepatitis** (Jaundice)	*Hepatitis/ virus*	Urine is dark and stool is pale.	Fever, anorexia, nausea, vomiting. Epigastric discomfort, pain in muscles and joints with liver get enlarged.
Trachoma	*Chlamydia trachomatis*	Direct contact, sharing cloths	Chronic inflammation of eye affecting cornea and conjunctiva, watering of eyes,

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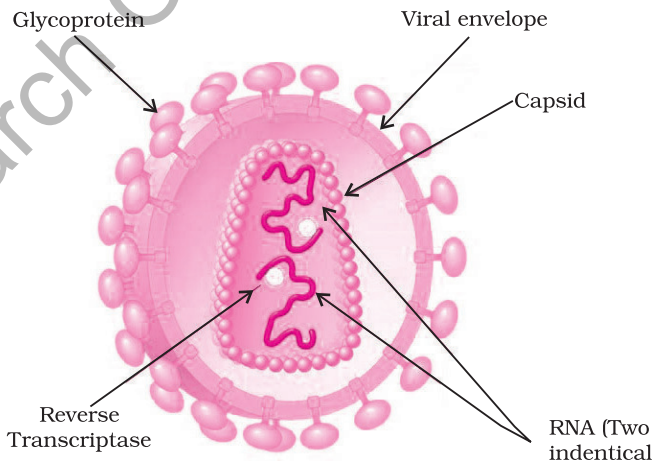
Rabies (Hydrophobia)	*Rabies virus*	Bite of rabid dogs, (also by infected) Jackals, Cat, wolves	After the bite of a rabid dog, cat, horse, etc., severe headache, choking of throat, hence, diffi-culty in swallowing, high fever etc.
Dengue fever (Break bone fever)	*Flaviribo virus*	Aedes Mosquitoes	Classical dengue: Abrupt high fever, headache, joint pains, loss of sense of taste and apetite, nausea, vomi-ting, and rashes on chest and upper limbs. Haemorrhagic dengue: symptoms like classical dengue along with bleeding from nose, mouth, pain in stomach, vomiting may be conta-minated with blood, restlessness with diffi-culty in breathing.
Chikungunya	*Chikungu-nya virus*	*Aedes Aegypti* mosquitoes	Abrupt onset of high fever, crippling joint pains, conjunctivitis.

- **AIDS (Acquired Immune Deficiency Syndrome) :** The infection is caused by HIV (Human Immuno-deficiency virus) by
  - unprotected sex
  - breast milk from the infected mother to her infant
  - transfusion of infected blood
  - sharing of fine piercing objects such as needles, razors with others.

The infection leads to decline in T-lymphocytes , prolonged fever, diarrhoea, lethargy, nausea, rashes, loss in body weight, loss in appetite.



HIV

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Diagnosis : ELISA test followed by Western blotting test. AZT (3'-azidoz,3'-dideoxythymidine) is used for delaying the onset of the symptoms while until now no confirmed drug is available for treatment.

Protozoa and infections in humans

Protozoans are unicellular protists, free living or parasitic. It's the parasitic forms which cause a number of diseases as listed below :

Disease	Causative agent	Mode of transmission	Symptom
Malaria	*Plasmodium sp./ vivax, falciprum, ovale, malariae*	Female Anopheles mosquito bite	Spread by bite of female anopheles cause intermittent fever, with chills and high temperature, headache, followed by profuse sweating, restlessness, body pains and anaemia. *P falciprum* is cerebral form of malaria that can be fatal.
Ciliary dysentery	*Balantidium coli*	Food and water	Ulceration of colon, diarrhoea.
Amoebisis	*Entamoeba histolytica*	Faeco-oral route, vectors: e.g. flies, cockroaches etc.	Inflammation of intestinal mucus membrane, dysentery with faeces contaminated with blood.
Trypanosomiasis (Sleeping sickness)	*Trypanosoma gambiense*	Tse tse fly	Spread by Tse-tse fly makes a patient lethargic and unconscious leading to death.
Giardiasis	*Giardia intestinalis*	Protozoa	Ist parasitic protozoan to be discovered causes epigastric pains, abdominal discomfort, diarrhoea, and slight fever.
Leishmaniaia (Black fever)	*Leishmania donovani*	Sand fly	Fever, loss of appetite, fatigue, enlargement of spleen and liver, suppression of bone marrow.

Helminthes and human diseases

- Helminthes stands for worms. There are two types of worms called flat worms and round worms belonging to the phylum Platyhelminthes and Aschelminthes. Many of the worms representative of these phylums cause infection and diseases to humans as given in the table below.

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Disease	Causa]tive agent	Mode of transmission	Symptoms
Taeniasis	*Taenia solium*	Contaminated food and water	Humans are primay hosts while pigs are the secondary hosts of the disease characterized by abdominal pains, restlessness, anaemia, insomnia, loss of appe-tite (anorexia).
Ascariasis	*Ascaris lumbricoides*	Eggs of parastic roundworm through vegetables and water	There is no secondary host. It is characterized by abdominal discomfort, diarrhoea, vomiting and false hunger pains.
Filariasis (Elephantitis)	*Wuhereria bancrofti Brugia* malayi	Filarial nematodes (Round worm)	Repeated attacks of fever, inflammation of lymphatic system, swelling of lower limbs giving them the form and size of an elephant with worms in lymphatic system. The enlarge-ment of limbs can only be removed by the surgical removal of the affected part.
Ancylostomiasis (Hook worm)	*Ancyclostoma duodenale*	Soil	Caused in people moving bare footed, inflammation of intestine, particularly duoden-um leading to mental and physical deficiency.
Oxyuriasis (Pin worm)	*Enterobolus vermicularis*	Faeco-oral route food, cloths etc.	Intense feeling of itching at anus, inflammation of mucous memb-rane of colon, appendix and rectum. Abdominal pain, dis-comfort and nausea.
Dracunculiasis (Guinea worm)	*Dranucnulus medinesis*	water	Appearence of blister on skin, nausea, vomiting, eosinophilia due to toxic secretion in body.
Fasicoliasis (Liver fluke)	*Fasicola hepatica*	*Uncooked* vegetables and meat	A termatode worm passes from uncooked or improperly cooked liver of a goat or sheep to man leading to the abdominal discomfort, nausea and inflammation of gall bladder and liver.

Fungal Infections in humans

- **Types of fungal infections :** There are a number of different types of infections caused by fungi. These commonly include:

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1. **Superficial infections :** These infections affect the skin or mucous membranes. Superficial fungal infections include (e.g., yeast vaginitis, oral thrush and athlete's foot)). Most of these infections are easily diagnosed and can be treated effectively.
2. **Systemic infections :** These occur when fungi get into the bloodstream and generally cause more serious diseases, hence, these infections can be life threatening.
3. **Opportunistic infections :** Fungi mostly attack the people with weakened immune systems. These can be either systemic or superficial infections.

- **Tinea Infections :** Superficial fungal infections of the skin, hair and/nails are extremely common. These include ringworm, jock itch and athlete's foot. Over the counter antifungal creams or sprays are often effective for limited infections. But some of these infections, such as scalp ringworm, typically require treatment with a prescription medication to kill the fungus.
- **Athlete's foot :** Known medically as *tinea pedis*, athlete's foot is a contagious fungal infection that affects the skin on the feet and can spread to the toenails and sometimes the hands. The fungal infection is called athlete's foot because it's commonly seen in athletes.
- **Candidiasis :** Candidiasis is a common type of fungal infection caused by different species of yeast in the Candida family. Candida yeast thrives on the moist surfaces of the body and is a common cause of vaginal infections. It can also cause an infection of the mouth or throat, known as thrush.

  Aspergillosis : Aspergillosis is a common fungus found in soil, decaying vegetation, insulating materials, air conditioning vents and dust. Aspergillosis spores float in the air and can be inhaled into the nose and lungs. In the people with weak immune system these spores infect the lungs and form growing fungal masses called aspergillomas.
- **Coccidioidomycosis :** It also known as San Joaquin Fever or Valley Fever; is a fungal disease caused by Coccidioides. This fungus inhabits dry areas, The infection causes symptomatic illness, headache, fever, muscle aches, cough and skin rash .
- **Pneumocystis pneumonia :** It is caused by the fungus *Pneumocystis jirovecii* and mainly affects the people with weakened immune systems with symptoms similar to pneumonia.

Immunity

Immunity : Refers to the general ability of a body to recognize, neutralize or destory and eliminate foreign substances or resist a particular infection or disease.

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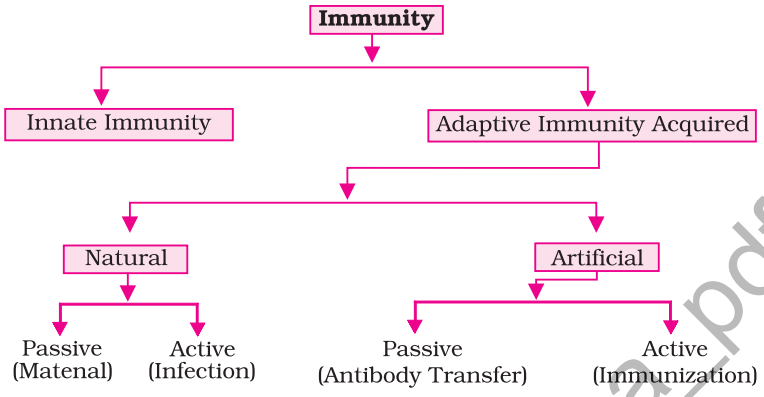
Types of immunity :



- **Innate immunity :** Innate immunity, also called non-specific immunity, is the natural resistance with which a person is born. It provides resistance through several physical, chemical and cellular approaches preventing the colonization, entry and spread of microbes such as WBCs in blood, epithelial layer of skin, presence of lysozyme in saliva and tears or of HCl in stomach body temperature, pH, phagocytic cells etc.
- **Adaptive immunity :** It can be naturally acquired immunity that develops through contact with a disease causing agent, when the contact was not deliberate, whereas 'artificially acquired immunity' develops only through deliberate actions such as vaccination. Acquired immunity is found only in the vertebrates.
- **Active v/s passive immunity :** Both naturally and artificially acquired immunity can be active or passive. 'Passive immunity' is acquired through the transfer of antibodies or activated T-cells from an immune host, and is short-lived usually lasting only a few months whereas 'active immunity' is induced in the host itself by antigens and lasts much longer, sometimes even lifelong.
- **Autoimmunity :** It refers to the system of the immune responses of an organism against its own healthy cells and tissues. Any disease that results from such an aberrant immune response is termed as an auto-immune disease.
- **Autoimmune diseases :** There are about 80 different types of auto-immune diseases. Some of these are listed below in the table.

S.No.	Disease	Cause
1.	Diabetes, Type-I	The body immune system acts on insulin producing beta-cells in pancreas.
2	Multiple sclerosis(MS)	The body immune system attacks myelin sheath which protects the central neurons in the spinal cord and brain

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3.	Crohn's & Colitis	It is also called inflammatory bowel disease in which the immune system attacks the intestines.
4.	Rheumatoid arthritis	The body immune system mistakenly attacks its own tissues particularly synovial membrane that lines the joints.
5.	Allergy	The body immune system overreacts in the presence of foreign substances called allergens such as pollen grains.
6.	Celiac disease	Also called gluten-sensitive enteropathy, it is a digestive disorder that results in damage to the lining of the small intestine when foods with gluten (type of protein) are eaten. The damage to the intestine makes it hard for the body to absorb nutrients, especially fat, calcium, iron and folate.
7.	Scleroderma	It is a disease of connective tissue in which skin becomes thick with spontaneous scarring of blood vessels.

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Minerals and deficiency diseases

- **Minerals :** These are specific kinds of nutrients that a body needs in order to function properly. A mineral deficiency occurs when a body doesn't obtain or absorb the required amount of a mineral.

  The human body requires different amounts of each mineral to stay healthy. Specific needs are outlined in recommended daily allowances (RDA). The RDA is the average amount that meets the needs of about 97 per cent of healthy people.

Causes of mineral deficiency :

- A poor diet that relies on junk food, or a diet that lacks adequate fruits and vegetables.
- A very low-calorie diet may produce deficiency.
- Restricted diets, e.g., vegetarians, vegans, and people with food allergies or lactose intolerance might experience mineral deficiency if they fail to manage their diet effectively.
- Difficulty in the digestion of food or absorption of nutrients can result in mineral deficiency. Potential causes of these difficulties include the diseases of the liver, gall bladder, intestine, pancreas or kidney, chronic alcoholism or medications such as antacids, antibiotics, laxatives and diuretics. Mineral deficiency can also

result from an increased need for certain minerals. Women, for instance, may encounter this need during pregnancy, heavy menstruation and post-menopause period.

Minerals, sources and deficiency symptoms

Mineral	Source	Deficiency disease and symptoms
Calcium (Men 800-1000) Women 700- 800 mg)	Milk, yogurt, cheese, and small fish with bones, beans, and peas. Vegetables such as broccoli, kale, and Chinese cabbage	Reduced bone mineral density is called osteopenia. If left untreated, it can turn to osteoporosis. This increases the risk of bone fractures, especially in older adults.Symptoms of a severe deficiency include cramping of muscles, numbness, tingling in fingers, poor appetite and irregular heart rhythms
Iron Men 8-10 mg Women 8-13 mg)	Beans, lentils, gram, meat, poultry or fish.	Iron-deficiency anemia include feeling weak and tired, feeling of early exhaustion, increased breathing rate.
Magnesium Men 230-250 mg Women 200-210 mg	Legumes, nuts, seeds, whole grains. green leafy vegetables, such as spinach Broccoli, beets, coconut, dates	Proper functioning of muscles and nerves, brain function, energy metabolism, and protein production require magnesium. Therefore, its deficiency symptoms include fatigue, weakness, loss of appetite, nausea, vomiting, numbness, muscle cramps and abnormal rhythms of the heart.
Potassium 3-6 g	Fruits and vegetables, such as bananas, avocado, dark leafy greens, beets, potatoes, plums, orange juice and nuts, sunflower seeds	Symptoms of potassium deficiency include muscle cramping and weakness. Other symptoms show up as constipation, bloating or abdominal pain caused by the paralysis of the intestines. Severe potassium deficiency can cause the paralysis muscles or irregular heart rhythms that may lead to death.
Zinc (9-12 mg)	Beans, nuts, whole grains, dairy products and sea foods. e.g. oysters, shrimp, Crab etc.	Zinc is necessory in functioning of many enzymes that are essential in digestion and metabolism. Deficiency can cause the loss of taste or smell, decreased function of the immune system and slowed growth. Severe deficiency can also cause diarrhoea, loss of hair and impotence. It can also prolong the process that a body takes to heal wounds.

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Iodine	Iodized salt, sea food	Causes goitre with the enlargement of thyroid gland in neck, other symptoms include cold intolerance, constipation, forgetfulness, personality changes, hair loss and weight gain.

Vitamin deficiency diseases and symptoms

➢ **Vitamin** : It refers to an organic compound and a vital nutrient that an organism requires in limited amounts for various biochemical functions.

Vitamin	Chemical form	Solu-bility	Requirement	Disease
A	Retinol, and four retinal, carotenoids including beta carotene	Fat	3,000 IU Carrot, spinach, milk banana, broccoli, liver, green vegatbles	Night blindness, hyperkeratosis, and keratomalacia. Problem with night vision. Xerophthalmia
B-1	Thiamine	Water	1.2 mg Sunflower, seeds, dried beans, whole grains, wild rice, wheat grass, meat	Beriberi, shortness of breath during physical activity, waking up short of breath, rapid heart rate and swollen lower legs. Wernicke-Korsakoff syndrome in alcoholics.
B-2	Riboflavin	Water	1.3 mg Vegetables, milk, egg white, Yeast, liver and kidney	Ariboflavinosis, glossitis, angular stomatitis with painful red tongue, sore throat, chapped and fissured lips (cheilosis), and inflammation of the corners of the mouth.
B-3	Niacin (Nicotine Acid	Water	16.0 mg Nuts, whole grain, mushrooms, fish, meat	Pellagra, 3-D disease di arrhoea, dermatitis (dry red skin with itching),dementia (forgetfulness)
B-5	Pantothenic acid	Water	5.0 mg Legumes, broc coli, whole grain, chicken	Paresthesia
B-6	Pyridoxine	Water	1.3-1.7 mg Green leafy veg etables whole wheat, banana, potato, toma toes, fish meat	Anaemia peripheral neu ropathy characterized by nerve damage

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B-7	Biotin	Water	30.0 mg carrots, eggs, milk, fruits nuts.	Dermatitis, enteritis
B-9	Folic acid	Water	400 µg broccoli, peanuts, papaya, asparagus, tomato, lettuce, spinach, meat etc.	Megaloblastic anaemia and deficiency during pregnancy is associated with birth defects, such as neural tube defects.
B-12	Cyanocobalamin	Water	2.4 µg Milk, and milk product meat fish, seafood, eggs.	Megaloblastic anaemia, acne-like rash.
C	Ascorbic acid	Water	90 mg Citrous fruits e.g. gooseberry, orange lemon, etc., guava, kivi, papaya, cauliflwer, grapes, sweet potato etc.	Scurvy, bleeding gums, delayed healing of wounds, appetite loss, poor weight gain, diarrhoea, rapid breathing, fever, irritability, tenderness and discomfort in legs, swelling over long bones
D	Calciferol	Fat	10.0 µg Sunlight, fortified foods, eggs etc.	Rickets with bow-shaped limbs and osteomalacia, bones being weak hence, becoming more prone to fracture.
E	Tocopherols	Fat	15.0 mg Olives, almonds, sunflowers seeds, nuts, green leafy, vegetables	Deficiency is very rare; sterility in males and abortions in females, mild haemolytic anaemia in newborn infants
K	Phylloqinone	Fat	120.0 µg Green leafy, vegetables, green peas, asparagus, etc.	Bleeding diathesis with increased blood clotting time.

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Non-infectious diseases in humans

Coronary artery disease(CAD) : It's a heart disease caused because of the blocking of coronary artery, the artery which supplies blood to the myocardium carrying muscles responsible for the beating of the heart. Its three principal causes include

- thrombosis, *i.e.* clotting of blood within artery such that the clot formed acts as a plug to stop further blood supply.

- arterosclerosis, it involves the hardening of the walls of artery so that they may lose their elasticity, hence, become prone to bursting.
- artherosclerosis, it involves the deposition of fats or cholesterol on the inside linning of artery that reduces the lumen and increases the blood pressure.
- **Types of diabetes :** There are two types of diabetes , a person can suffer from, each with its own cause. These are:
- **Diabetes mellitus :** It is caused by failure in the metabolism of glucose either because of the non-secretion of insulin from the beta cells of pancreas(Type-I) or non-absorption of glucose (Type-II). However in both cases, the blood sugar level rises above normal, *i.e.* 90-92 mg/100mL of blood.
- **Diabetes insipidus (DI) :** It is a condition characterized by excessive thirst and excretion of large amounts of severely dilute urine. The most common type in humans is because of a deficient secretion of vasopressin (AVP), also known as antidiuretic hormone (ADH).
- **Emphysema :** It is a long-term, progressive disease of the lungs that primarily causes the shortness of breath due to the over-inflation of the alveoli (air sacs in the lung). In the people with emphysema, the lung tissue involved in the exchange of gases (oxygen and carbon dioxide) is impaired or destroyed. Mostly, it occurs in smokers, hence, also called smoker's disease because tar present in cigarette smoke gets deposited in alveoli and blocks them.
- **Cirrhosis :** It is a condition in which the liver does not function properly due to long term damage, particularly caused by excessive intake of alcohol. There is the condition of hardening of liver. The person becomes tired, weak, itchy, has swelling in the lower legs, develops yellow skin, bruises easily, has fluid build-up in the abdomen, or develops spider like blood vessels on the skin.
- **Cancer :** It's a Latin word for a 'crab' as it refers to any abnormal growth of cells which tend to proliferate in an uncontrolled way. However, there are two types of cancer.
  1. **Benign tumours :** These aren't cancerous. They can often be removed, and, in most cases, they do not come back. Cells in benign tumours do not spread to the other parts of the body.
  2. **Malignant tumours :** These are cancerous and are made up of cells that grow out of control. Cells in these tumours can invade nearby tissues and spread to the other parts of the body. Sometimes cells move away from the original (primary) cancer site and spread to other organs and bones where they can continue to grow and form another tumour at that site. This is known as metastasis or secondary cancer.

  Hence, malignant cancer is more threatening than benign cancer.
- **Causes of cancer :** There is a wide range of the type of cancers, either acquired or inherited. The recent studies have revealed

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the presence of oncogenes in many people suffering from cancer. The acquired cancer is caused by the intake of substances called carcinogenic substances such as smoke, eating colours, radiations, U V rays, radioactivity, mutations etc.

Main diagnostic techniques in Medical Science

- **MRI :** Magnetic resonance imaging (MRI) is a type of scan that uses strong magnetic fields and radio waves to produce the detailed images of the inside of the body. An MRI scanner is a large tube that contains powerful magnets. A person lies inside the tube during the scan.
- An MRI scan can be used for examining almost any part of the body, including the brain and spinal cord, bones and joints, breasts, heart and blood vessels, internal organs, such as the liver, womb or prostate gland
- The results of an MRI scan can be used for helping diagnose conditions, plan treatments and assess how effective previous treatment has been.
- **CT scan (Computed tomography) :** It is a diagnostic medical test that, like traditional x-rays, produces multiple images or pictures of the inside of the body. The cross-sectional images generated during a CT scan can be reformatted in multiple planes, and can even generate three-dimensional images. CT images of internal organs, bones, soft tissues and blood vessels typically provide greater detail than traditional x-rays, particularly of soft tissues and blood vessels for the diagnosis of cancer, cardiovascular disease, infectious disease, appendicitis, trauma and musculoskeletal disorders.
- **Ultrasonography :** It is a diagnostic imaging technique based on the application of ultrasound. It is used for seeing internal body structures such as tendons, muscles, joints, vessels and internal organs. Its aim is often to find a source of a disease or to exclude any pathology. The practice of examining pregnant women using ultrasound is called obstetric ultrasound. It is useful to examine the growth and development of foetus and examine the congenital anamolies etc. and is widely used.
- **ELISA test :** An Enzyme Linked Immunosorbent Assay is a test that detects and measures antibodies in blood. This test can be used for determining if one has antibodies related to certain infectious conditions. Antibodies are proteins that a body produces in response for harmful substances called antigens. An ELISA test may be used for diagnosing HIV, which causes AIDS, Lyme disease, pernicious anaemia, Rocky Mountain Spotted Fever (RMSF), squamous cell carcinoma, varicella-zoster virus, which causes chicken pox.
- **Biopsy :** A biopsy is a sample of tissue taken from the body in order to examine it more closely. A doctor recommends a biopsy when an initial test suggests the an area of tissue in the body isn't

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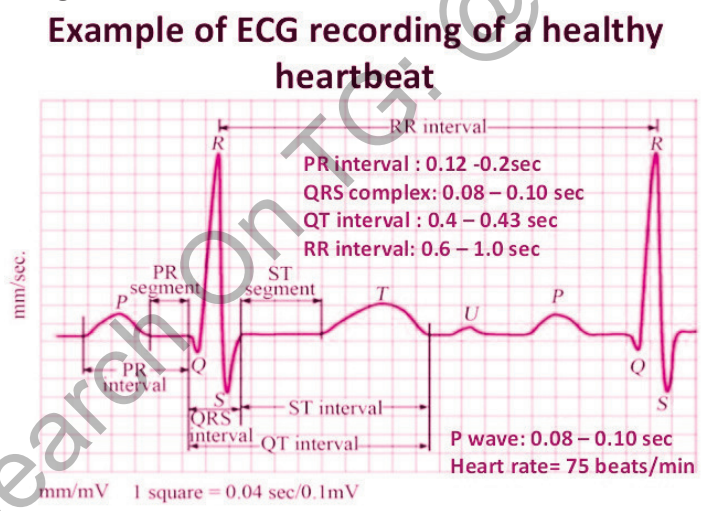
normal. The abnormal tissue may be a lesion, a tumour or a mass. Biopsies are most often done to look for cancer.

- **Widal test :** The Widal test developed in 1896 and named after Georges Ferdinand Widal is one method that is used for helping make a presumptive diagnosis of enteric fever, also known as typhoid fever.
- **Tuberculin skin test :** A tuberculin skin test (also called a Mantoux tuberculin test) is done to see if one has ever been exposed to tuberculosis (TB). The test is done by putting a small amount of TB protein (antigens) under the top layer of skin on one's inner forearm. If one has ever been exposed to the TB bacteria (*Mycobacterium tuberculosis*), the skin will react to the antigens by developing a firm red bump at the site within 2 days, otherwise not.
- **ECG (Electrocardiogram) :** It is a test that checks for problems with the electrical activity of the heart. An ECG shows the heart's electrical activity as line tracings on paper. The spikes and dips in the tracings are called waves. It also helps to find the cause of unexplained chest pain or pressure. This could be caused by a heart attack, inflammation of the sac surrounding the heart (pericarditis) or angina.



- **EEG (Electroencephalogram) :** It is a test that measures and records the electrical activity of the brain. Special sensors (electrodes) are attached to head and hooked by wires to a computer. The computer records the brain's electrical activity on the screen or on paper as wavy lines. Certain conditions, such as seizures, can be seen by the changes in the normal pattern of the brain's electrical activity. It helps in finding epilepsy, problems with loss of consciousness or dementia, sleep disorder such as narcolepsey.

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Chapter 12

PLANT PATHOLOGY

Infectious diseases caused by viruses, bacteria and fungi among plants

Bacteria and plant diseases

Most bacteria in the environment are beneficial but several are able to cause leaf spots, stem rots, root rots, gall wilts, blights and cankers. Most plant pathogenic bacteria belong to the following genera: *Erwinia, Pectobacterium, Pantoea, Agrobacterium, Pseudomonas, Ralstonia, Burkholderia, Acidovorax, Xanthomonas, Clavibacter, Streptomyces, Xylella, Spiroplasma and Phytoplasma*

BIOLOGY

List of phytopathogenic bacteria

Bacteria	Symptoms in the affected plants
Erwinia chrysanthemi	It mainly causes soft rot disease. It attacks on xylem vesseles. Mushy, brown, smelly, soft rot or leaf spots among greenhouse plants. Fire blight of pear and apple, Stewart's wilt in corn, and soft rot of fleshy vegetables.
Pseudomonas cichorii	Symptoms: leaf blighting, spotting. Leaf spots and blights on chrysanthemum, geranium, impatiens, and many other ornamental plants. The spots are generally water-soaked and dark brown to black.
Rhodococcus fascians	Abnormal branching and stem development near the base of the infected plants such as geranium. Stems suffer from stunting or rosetting and witches broom.
Ralstonia solanacearum	Vascular wilting of many herbaceous ornamentals that leads to leaf wilting, overall stunting, discolouration of tuber eyes, discolouration of the vascular tissue, leaf yellowing and death of the plant.
Xanthomonas vesicatoria	It causes bacterial leaf spot (BLS) Affects pepper, tomato and several of weedy members of the Solanaceae family. Symptoms vary with host plant and can develop on the leaves, stems and fruits. On a tomato, initial symptoms on leaves and stems appear as tiny, water-soaked, black, circular spots leading to death. On pepper, initial symptoms appear as small, yellow-green, circular lesions surrounded by yellow haloes. As the lesions mature, the symptoms develop as brown to black, raised or sunken, a wart-like lesion on a fruit.

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Pseudomonas syringae	It is an opportunistic pathogen that attacks a wide variety of woody plants. Bacterial speck with symptoms that develop on leaves, petioles, stems and fruit. On leaves, symptoms appear as tiny, black specks, not more than 1/10th inch in diameter and are surrounded by yellow haloes. When the spots are numerous, they coalesce and give the leaf a distinctly chlorotic appearance.
Clavibacter michiganensis	Bacterial canker in a tomato. Symptoms are variable and include stunting, wilting, vascular discolouration, cankers on stems, and lesions on fruits, desiccation of the edge of the leaflets.
Xanthomonas campestris	All members of the Brassicaceae family including broccoli, brussels sprouts, cabbage, cauliflower, Chinese cabbage, kale, mustard, radish, rutabaga and turnip. Symptoms develop on the above-ground parts of plants at any stage of growth. Bacteria enter and colonize natural openings (e.g., stomatas, hydathodes) and wounds. On true leaves, diagnostic symptoms appear at leaf margins as yellow V-shaped lesions. The lesions enlarge towards the base of the leaf and the affected tissues wilt and die. This is frequently accompanied by a distinct blackening of the veins. e.g. black rot.
Erwinia tracheiphila :	Bacterial wilt of cucurbits, most prevalent on cucumbers. Symptoms include the wilting of individual leaves or vines. The disease first appears as dull-green patches on the leaves which quickly increase in size causing the leaf to wilt completely and die.
Serratia marcesccens	Yellow vine disease of cucurbits. It is also pathogenic in human.
Genus- Acidovorax	Leaf spots in corn, orchids and watermelon.
Rhizobacter	Bacterial gall of carrots.
Rhizomonas	Corky root rot of lettuce
Genus-Xylella	Xylem-inhabiting, causing leaf scorch and dieback disease on trees and vines.
Bacillus clostridium	Rot of tubers, seeds and seedlings, white stripe of wheat, rot of stored tubers and leaves and wet wood of elm and poplar.

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Candidatus liberobacter	It primarily spread by psyllid insect vectors. It is very invasive. It is phloem inhabiting, causing citrus greening disease. Unnamed, laticifer inhabiting, causing bunchy top disease of papaya.
Clavibacter curtobacterium	Bacterial wilts in alfalfa, potato and tomato. Bacterial wilt in beans and other plants.

Some useful bacteria

Taxon	Function
Agrobacterium radiobacter	Biological control
Agrobacterium sp.	Source of an experimental drug for cholesterol degradation
Agrobacterium radiobacter	Biodegradation of Atrazine, an agricultural herbicide
Agrobacterium tumefaciens	Plasmid vector for plant transformation (genetic engineering)
Erwinia amylovora	Source of heprin (*Messenger*), an elicitor of disease resistance in plants.
Xanthomonas campestris pv.*campestris*	Xanthan gum, a polysaccharide used in food production, agriculture, cosmetics and pharmaceuticals, biosynthesis of sugar nucleotide precursors.

- **Viral infections in plants :** Cucumber mosaic virus , rodent's mottle virus and tomato spotted wilt virus are the commonly known viruses which infect plants. Some of these include:

Disease	Causative agent	Symptoms
Alfalfa mosaic	*Alfalfa mosaic virus*	Destructive disease of a tomato because of the severe damage caused to the fruit. Symptoms include bright yellow mosaic of newly expanded leaves and an extensive browning and splitting of the fruit. Reduced root system, discolouration of barks.
Curly top or western yellows disease	*Beet curly top virus*	Yellowing and curling of leaves, plants appear pale green and stunted as new growth is stopped. On plants that develop symptoms after fruit have set: The fruit prematurely ripens and becomes dull red and wrinkled.
Tobacco mosaic	*Tobacco mosaic*	It causes "mosaic" like mottling and discoloration on the leaves. Reduced number, size and

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	virus (TMV)	marketability of the fruit, mottled areas of light and dark green colour. Infected leaves are small, curled and malformed and plants have uneven ripening of fruits.
Tomato spotted wilt	*Tomato Spotted Wilt Virus (TSWV) and Impatiens Necrotic Spot Virus (INSV)*	Stunting of new growth, a brown spotting or bronzing of young leaves and brown streaking on terminal stems. Dark purple to brown ring spots in some leaves. Plants infected fail early to set any fruit, while those infected after fruit have set produce fruit with ring spots and are off-flavour.

Fungal infections in plants

- Fungi is a large and diverse group of micro-organisms. They are actually cells that consist of a membrane bound nucleus and are devoid of chlorophyll. They also have rigid cell walls. These fungi have vegetative bodies, of which some parts extend into the air and others penetrate the substrate of the organisms that they grow on.
- Fungi propagate through sexual as well as asexual methods and spread through spores that are produced in abundance. These spores are transmitted on plants through wind, water, soil, birds and insects. Fungi are responsible for approximately two-thirds of the infectious plant diseases. There are many plant diseases caused by fungi, like mildew, smuts, rusts, etc.

Infection	Symptoms
Brown patch	It is a turf grass disease caused by different species of the *Rhizoctonia* fungus. Patches of brown and yellow colour appear on the lawn in irregular shapes. It does not affect the roots and crown of grass, hence, also called as Foliar disease.
Canker	Some fungal infections affect the roots and barks of plants. One such is caused by canker fungi. It is found on woody trees and is notorious for causing localized damage to the barks of trees, hence structurally weakens a plant.
Downy mildew	It affects foliages of many ornamental and edible plants. It is caused by *Peronosporaceae* which affects a number of plants. It can be identified when discoloured blotches appear on leaves a mould-like growth also develops on plants. It affects the growth and strength of a plant.

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Club root	It is found in cabbages, turnips and radishes which is caused by the *Plasmodiophora brassicae* fungus. The colour of leaves changes to bluish-green, and the roots if pulled out appear clubbed and are easily broken.
Black spot	*Diplocarpon rosae* is the fungus that causes the black spot disease on a rose plant in humid climate. Blackish spots that appear on the leaves gradually spread upwards and weaken the plant.
Anthracnose	It is a disease caused by *Colletotrichum or Gloeosporium* fungi which occur in warm and humid areas. In this, dark, water soaked lesions appear on stem stems, leaves, fruits and shrunken kind of spots of different colours are observed on fruits, flowers, stems and leaves. These spots gradually expand and cause the plant to die.
Bottom rot	This is a fungal disease found on lettuce plants caused by *Rhizoctonia solani* .The characteristic feature of this fungus is that it first affects the leaves on the lower part of the plant and then moves upward to affect the upper part.
Crown wart	This disease is caused by a fungus of *Physoderma* species that attacks the stem of the alfalfa plant. It forms white protrusions at the base of the stem of the plant, and galls around the base of the stem.
Red thread	This is a common disease that affects lawns which occurs generally in autumn and summer, caused by *Laetisaria fuciformis* fungus. Red-coloured patches appear on the grass in the beginning and gradually kill the whole grass if no action is taken.
Dry rot	It is caused by *Serpula lacrymans*, also known as true dry rot fungus. This disease in plants causes the drying and crumbling of timber, bulbs, potatoes or fruits and is commonly found all over the world.
Potato wart	It is caused by *Synchytrium endobioticulum* that causes dark, warty, spongy excrescences in the eyes of potato tubers.
Rhizoctonia disease	*Rhizoctonia solani* is the fungus that infects potato plants, underground stems and tubers as well. It generally occurs in the lesion form, or as sclerotia on tubers. This infection kills the plant as it does not allow the plant to grow further.

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Late blight	Late blight or blight is caused by *Phytophthora infestans*. It causes grey spots and white-colored moulds to start appearing on the leaves of potatoes and tomatoes as well as fruits, eventually killing the whole plant.
Early blight	*Alternaria solani* is the fungal pathogen that causes early blight disease in potatoes and tomatoes. It destroys the fruit of the plant and affects the life as well. The leaves and fruits turn yellow or brown and then drop off from the plant.
Plant wilting	Wilting means loss of rigidity of non-woody parts of plant. This fungal disease causes the plant (it infects) to wilt. The fungal invasion starts in the roots and then slowly makes its way into the stem and plugs of the vascular system of the plant. Fusarium wilt (caused *by Fusarium oxysporum*) and Verticillium wilt (caused by *Verticillium longisporum*) are the types of plant wilting that affect many plants, like cotton, potato, tomatoes, tobacco and so on.
Leaf curl	It is a disease caused by *Taphrina deformans* in which leaves appear distorted, crumpled, and thickened and curling. It reduces the production of leaves and fruits.
Gray mold	It is caused by *Botrytis*, which forms a white-coloured growth on plants that gradually turns into grey colour. The fruits and leaves of the infected plant fall while the stems break down especially in cool to mild weather.
Apple scab	It is a serious disease of apples and ornamental crabapples. It is caused by *Venturia inaequalis*, an air-borne fungus. Olive green-coloured patches appear on the leaves, black- or grey-coloured patches develop on fruits, eventually destroying them.
Powdery mildew	It is often specific to the host that it invades. It is normally seen on roses, lilac, English oak, zinnias, etc.
Pink root	This infection is mostly found in onions caused by *Phoma terrestris*, a soil-borne fungus. It can be identified by light pink to yellowish brown discolouration of the roots of the onion. It affects the growth of the plant to quite an extent.

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Rust	This disease caused by *Puccinia sp.* affects the stems, leaves, seeds and fruits of the plant. It can be identified if the spots of brown, yellow, red or orange colours are seen. It may reduce the vigour of the plant.
Cotton ball	This is a disease of cranberry plant which is caused by *Monilinia oxycocci* fungus. Cotton-like fungus appears inside berries, infects them and spoils the whole fruit.
Smut	*Ustilago maydis* is a fungus that affects corn, wheat, sorghum and sugarcane plants. Blisters develop on the affected parts of the plant and it gets discoloured as well. The kernels become huge; they swell up and the whole plant and fruit are slowly destroyed.
Wet rot	It is generally seen in the rainy or damp areas, due to excess moisture, mostly affecting timber. It is caused by *Coniophora puteana* or *Poria vaillantii*. Wet rot mostly results in the decaying of the plant.
Yellow spots	These spots are caused by *Pyrenophora tritici-repentis* fungus. Yellow-coloured spots develop on leaves and the stem, and if not taken care it dries up or infects the whole plant.
Black rot	It is a disease of cultivated plants, which occurs due to humid and damp weather conditions. This disease is characterized by the darkening and decaying of the leaves of fruit and vegetable plants. It is commonly found on grape vines, cabbage, orchids and many more. Grape black rot is a disease caused by *Guignardia bidwellii* that specifically affects grape vines during hot and humid weather.

Natural plant protection : Plants like animals have some innate chracteristics to protect them from infections such as

- Many plants have impenetrable barriers such as bark and waxy cuticles or adaptations such as thorns and spines to protect them from pathogens.
- If pathogens breach the barriers of a plant, the plant tries to respond with secondary metabolites which are often toxic compounds such as glycol cyanide that may harm pathogens.
- Some plants produce anti-microbial chemicals, anti-microbial proteins, and anti-microbial enzymes that are able to fight against pathogens.

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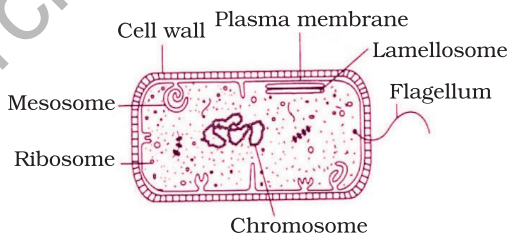
Chapter 13

MICRO-ORGANISMS: FRIENDS TO MANKIND

Bacteria and their types, role of bacteria in industries , role of bacteria in the production of antibiotics, fungi and their importance in agriculture, production of food products and in production of antibiotics, algae and their economic importance.

- **Microorganisms :** Micro-organisms or microbes are microscopic organisms that exist as unicellular, multicellular or cell clusters. Micro-organims are widespread in Nature and are beneficial to life, but some can cause serious harm. They can be divided into six major types: bacteria, archaea, fungi, protozoa, algae and viruses.
- **Bacteria** (sing.: Bacterium) : These are microscopic single-celled prokaryotic organisms that can thrive in diverse environments. They can live within soil, in the ocean, inside the human gut, hot water springs or in biogas tank, etc.
- **Structure of a bacterium :** The entire organism consists of a single cell with a simple internal structure having DNA that floats free, in a twisted thread-like mass called the nucleoid along with separate, circular pieces of DNA called plasmids in some. It lacks membrane-bound organelles, However, both bacterial and eukaryotic cells contain ribosomes.
- On the outside, bacterial cells are generally surrounded by two protective coverings, an outer cell wall and an inner cell membrane with mesosomes.
- Mycoplasms: These are bacteria which lack cell walls, *i.e.* these are bacteria without cell walls. They are the smallest organisms.
- Some bacteria may even have a third, outermost, protective layer called the capsule. Some of them have found to possess long flagella and small pili. The flagella help in motility while short pili help them to attach to host surfaces.



Structure of a bacterial cell

- Bacterial species are differentiated by morphology, chemical composition, nutritional requirements, biochemical activities and sources of energy.
- Structurally, most bacteria are 0.2 um in diameter and 2-8 μm in length.

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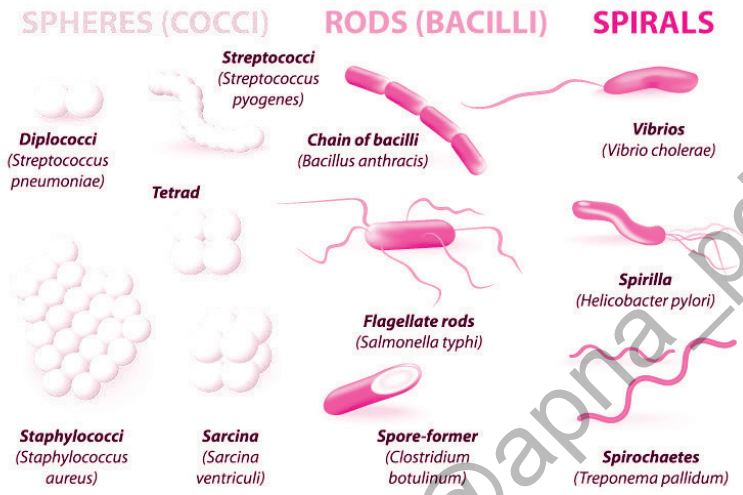
- **Types of bacteria based on shape:** Bacteria are unicellular and most multiply by binary fission.

Shapes of Bacteria



- The three basic bacterial shapes are coccus (spherical), bacillus (rod-shaped), and spiral (twisted). However, pleomorphic bacteria can assume several shapes.

  Diplococci : Pair of coccus

  Streptococci : Linear chain of cocci

  Staphylococci : Cluster like a bunch of grapes

  Vibrio : Comma-shaped like curved rods

  Spirochete : Helical shape and flexible bodies, like corksrew shaped, long and thin.

  Spirillum : Helical shape and fairly rigid bodies.

- **Classification of bacteria :** The Gram stain is a test used for identifying bacteria as Gram +ve or Gram-ve. Bacteria are first stained with a purple dye called crystal violet. Then the cells are stained with a second red-coloured dye called safranin. Gram-positive bacteria stain purple while the Gram-negative bacteria whose cells walls have two layers take on a red colouring. The outer layer of lipids does not bind strongly to crystal violet and the dye is easily washed away during the staining process.
- *Streptococcus pneumoniaee* is a Gram+ve bacterium, while *Escherichia coli* (*E.coli*) and *Vibrio cholerae*, are Gram-ve bacteria.

Bacteria and their uses to mankind

- ***Lactobacillus acidophilus :*** There are more than 8O species. Some of these reside in the intestines where they help in the digestion of food. *L. acidophilus* (LAB) produces lactic acid and hydrogen peroxide, which create unfavourable conditions for the growth of harmful bacteria. One way to get L. acidophilus diet is to eat yogurt. It is also a probiotic.

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- In fermentation, lactic acid bacteria ferment the lactose present in milk into lactic acid leading to the precipitation of the proteins forming thickened curd.
- **Whey :** It is the remaining liquid after milk curdling.
- ***Lactobacillus bulgaricus and Streptococcus thermophilus* :** Classic yogurt is the result of the fermentation of these two main bacterial species. Yogurt is most often made of a cow's milk although milk from a sheep, goat, water buffalo, camel and yak is used as well.
- ***Lactococci, Lactobacilli, Streptococci* :** Cheese is another popular dairy product. It consists of milk proteins and fat together with lactic acid bacteria. It has longer shelf life than uncultured milk. Currently, there are a few hundred varieties of cheese produced all over the world.
- **Making of cheese :** Making cheese first involves acidification usually with lactic acid bacteria; the solids are separated from the whey by coagulation with rennet and processed further to yield the final product, the cheese. Depending on the type of cheese, the solids could go straight to packaging or other bacteria or mould could be added to ripen the cheese, e.g.,
  Propionibacterium sharmanii is added to produce Swiss cheese,
  Penicillium mould for blue cheese.
  Streptococci sp. for soft cheese, etc.
- **Rennet :** It is a mixture of proteases and lipases enzymes extracted from a mammalian stomach.
- Other fermented and widely consumed cultured dairy products include kefir (lactic acid bacteria and yeasts are used for the fermentation), sour cream (fermented cream), cultured buttermilk (fermented cow's milk with *Streptococcus lactis or Lactobacillus bulgaricus only)*
- **Fermentation bacteria :** These are anaerobic, but use organic molecules.
- *Leuconostoc and Streptococcus*, species of bacteria ferment rice and black gram for the making of dosa and idli.
- *Lactobacillus, Bacillus and Streptococcus* are used for producing **lactic acid**.
- Escherichia and Salmonella produce ethanol, lactic acid, succinic acid and acetic acid.
- **Acetic acid bacteria (AAB) :** These are Gram-negative bacteria which oxidize sugars or ethanol to produce acetic acid during fermentation. The main acetic acid bacterium is *Acetobacter aceti.* Presently the conversion of ethanol to acetic acid for making vinegar is the well-known application of ABA.
- **Clostridium butyricum, C. kluyveri, and Megasphaera spp :** These are known to be involved in the production of butyric Acid, a carboxylic acid that is produced during glucose fermentation, and is generally considered an off-flavour in sour beer.
- **Propionibacterium, i.e. P. pentosaceum and P. shermanii** : The formation of propionic acid by the decarboxylation of succinate occurs in the presence of the above-mentioned bacteria.

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- **Bacteria and production of amino acids :** Amino acid dehydrogenases from certain bacteria such as *Bacillus megaterium* can be used in the amination of α-keto acids for producing L-amino acids, e.g., alanine (from pyruvate), leucine (from α-ketoisocaproic acid) and phenylalanine (from phenyl pyruvate).
- L-Lysine is predominantly produced by *Corynebacterium glutamicum* and to some extent by *Brevibacterium flavum or B. lactofermentum.*
- L-Glutamic acid was the first amino acid to be produced by micro-organisms, original bacterium, *Corynebacterium glutamicum* was used. Now brevibacterium and arthobacter is also used.
- *E. coli* and *C. glutamicum* can be used in the production of L-phenylalanine and threonine.
- **Bacteria and inorganic acid production :** Many of the inorganic acids such as sulphuric acid , sulphrous acid , nitric acid and carbonic acid can be produced by the activity of bacteria, particularly the bacteria belonging to genus *Thiobacillus* are actively involved in the production of sulphrous and sulphuric acid in deep ground diposits. Some others include species such as *Thiothrix and Begglatoa spp.*
- **Bacteria and metal corrosion :** Bacteria belonging to genera *Pseudomonas and Shwanella* have been found to reduce manganese or iron oxide reduction. The bacteria of genera *Gallionella* and *Leptothrix* have tendency to oxidize Mn^{2+} to Mn^{3+} as well as Fe^{2+} to Fe^{3+}.
- **Bacteria in agriculture :** The bacteria *Rhizobium* which live in symbiotic relationship with the roots of legume plants fix atmospheric nitrogen into simple nitrogen compounds *i.e.* nitrates and nitrites that can be absorbed and used by a plant. Hence, they help maintain the soil fertility.
- **Bacteria and retting of fibres :** Retting is a process of separating fibre from the stem. It is used in the production of fibre from plant materials such as flax and hemp stalks and coir from coconut husks.
- Some species of aerobic bacteria such as *Bacillus subtilis, Bacillus mesentericIus,* and *Bacillus macreans* have retting ability. *Bacillus corchorus*, an anaerobic bacteria, is used for retting jute stems.
- **Bacteria and tanning of leather :** Tanning is the process that converts the protein of the raw hide or skin into a stable material which will not putrefy and is suitable for leather production. Traditionally for tanning, a number of bacterial and fungal species are being used such as *Bacillus and Stretomyces spp. of bacteria, Aspergillus niger* and *Rhizopus* species of fungi.
- **Raw hides v/s tanned hides :** The principal difference between the two is that raw hides dry out to form a hard inflexible material that can putrefy when it gets moisture but tanned material dries out to a flexible form that does not become putrid when wetted back.

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- **Bacteria in paper industry :** The xylanase enzymes from *Streptomyces roseiscleroticus*, *Saccharomonospora viridis*, and *Streptomyces* sp. are being used in the treatment of pulp in paper industry.
- **Bacteria and polymer industry :** A huge variety of biopolymers, such as polysaccharides, polyesters, and polyamides, are naturally produced by micro-organisms. These range from viscous solutions to plastics. Plant-pathogenic bacteria of the genus *Xanthomonas* are able to produce the acidic exopolysaccharide xanthan gum.
- **Coffee and cocoa seeds fermentation :** The fermentation is carried out by fungi or bacteria. The bacterial side of the fermentation is conducted by lactic acid bacteria, some Enterobacteriaceae and Bacillus. The most common bacteria to produce pectolytic enzymes are *Pseudomonas (P. fluorescens)* and *Erwinia (E. carotovora).* Of these, only Erwinia is fermentative.
- **Bacteria and drugs :** An antibiotic is a drug that kills or slows down the growth of bacteria. Antibiotics are chemicals produced by or derived from micro-organisms. The first antibiotic was produced by Alexander Fleming in 1928 in a significant breakthrough for medical science.
- **Tetracyclines** used in the treatment of the infections of the respiratory tract, sinuses, middle ear, urinary tract, skin, intestines are derived from a species of *Streptomyces* bacteria.
- **Macrolide antibiotics** such as erythromycin, azithromycin , roxithromycin, etc. are bacteriostatic, which bind with bacterial ribosomes to inhibit protein synthesis. Erythromycin is similar to penicillin in action. These drugs derived from *Streptomyces* bacteria are used for treating respiratory tract infections (such as pharyngitis, sinusitis and bronchitis), genital, gastrointestinal tract, and skin infections.
- **Polymixin** an anti-fungal preparation is prepared from *Bacillus polymyxa*. They are useful against skin infections.
- **Bacitracin** used in the treatment of syphilis, reticulosis and lymphonema is prepared using *Bacillus licheniformis.*
- **Bacteria in human health and diseases :** Bacteria can be beneficial as well as detrimental to human health. Commensal bacteria, which share space and resources within our bodies, tend to be helpful. According to recent studies, there are about 10 times more microbial cells than human cells in the human body. The highest numbers of these microbial species are found in the gut.
- Several bacteria ranging from group *Streptococcus*, *Clostridium*, *Escherichia coli* and *Staphylococcus aureus* cause a rare but severe soft tissue infection called necrotizing fasciitis, hence, sometimes they are called **"flesh-eating bacteria.** The infection with these bacteria affects the tissues surrounding muscles, nerves, fat and blood vessels as you have learnt in the previous Unit-12.
- **Archaea or Archaebacteria :** These are bacteria but differ from true bacteria in their cell wall structure and lack of peptidoglycans. They

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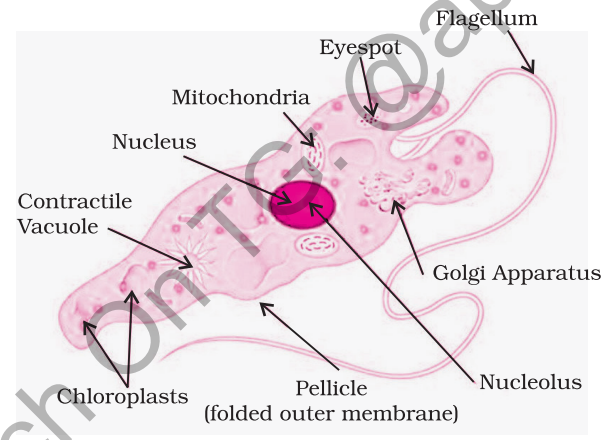
are prokaryotic cells with ability to survive in extreme environmental conditions. Based on their habitat, they have neen grouped as : methanogens (methane-producing organisms), halophiles (living in salty environments), thermophiles (living at extremely hot temperatures), and psychrophiles (cold temperature).

- Of all these, methanogens are widely used in the production of biogas in a biogas plant.
- Archaeans use different energy sources like hydrogen gas, carbon dioxide and sulphur. Some of them use sunlight to make energy, but not the same way plants do. They absorb sunlight using their membrane pigment, bacteriorhodopsin. This reacts with light, leading to the formation of the energy molecule Adenosine Triphosphate (ATP).

Economic importance of algae

Algae are aquatic green organisms. Many of their species are of importance to mankind in different ways other than being the major contributor of oxygen. Some of their importance includes:



Algae Cell Diagram

- **Algae as food :** Algae are rich in carbohydrates, inorganic substances and vitamins. Vitamins A, B_1, B_7 B_{12} C, D and E are the main constituents of these plants. *Parphyratenesa* is very popular and eaten throughout Japan. Kambu is another product of algae. *Laminaria* is used in Japan as standard food. *Spirogyra,* the chief source of food ulva (sea lettuce), is also used by man as food. Recently, green alga chlorella has drawn attention because the percentage of protein in this algae is higher than other vegetable or even an egg. It also contains vitamins A to D.
- Algae are also the rich source of minerals these are also called as seaweed wich are rich in iron, Magnesium, potassium, zinc etc.
- Algae are used for decorating pastries, sandwitches, rice, fish, cakes and jelly cakes in Japan. Agar-agar is used in the preparation of

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ice-cream and jellies. Geliduim, Gracillaria algae are the chief source of agar-agar. Alga *Rhodomenia palmata* is chewed like tobacco in Scotland.

- **Algae in industry :** Diatoms (algae) prepare diatomaceous earth and are extensively used in sugar refineries and soap manufacture. They are helpful in the manufacture of dynamite, rubber and blotting paper as an abrasive in metal polishes and toothpastes, absorbents etc. They are also used in the isolation of boilers, blast furnaces and at various other places where very high temperature (1000°C) is required.
- The Japanese prepare artificial wool from sargassum. Agar-Agar obtained from algae like Geliduim is used in the sizing of textiles. Algae *chondrus* and *Careragaenium* yield a mucilage used in the manufacture of cosmetics, shaving creams, shoe polishes and shampoos. Various red algae like laminaria yield Iodine. Several sea weeds also yield bromine, acetic acid, formic acid and acetone.
- **Algae in agriculture :** Presence of mucilage in most of the members of Myxophyceae helps in development and better nourishment for nitrogen fixing bacteria. Some of them like Anabaena, Nostoc, etc. are able to utilize and fix atmospheric nitrogen, thus increasing soil fertility. Some members of myxophyceae are able to fix 20 lbs. of atmospheric nitrogen per acre in rice field.
- **Algae in medical science :** Green unicellular algae chlorella yield an antibiotic known as chlorellin. It is crystalline and stable at 120°C. It has marked effect on gram positive and gram negative bacteria. Presence of *Chara* and *Nitella* algae in a pond causes the death of mosquito larvae thus helping in the control of malaria to some extent.
- **Algae in biological research :** Most of the information on photosynthesis and metabolism is based on the studies of unicellular algae such as *chlorella*. Certain algae like *chlamydomonas* are being used in genetical studies.
- Chlamydomonas was the first haploid organism on which successful hydridization was accomplished.
- Certain algae like *Acetabularia, Valonia* and *Nitella* show great success in studies on morphogenesis, nuclear function, nuclear cytoplasmic relationship and ionic exchange with the environment.

Economic Importance of Fungi

Fungi are important to human life on many levels. They influence the well-being of human populations on a large scale because they are part of the nutrient cycle in ecosystems. They also have other uses, such as pesticides, and in the production of varied types of antibiotics.

- **Biological Insecticides :** Some fungi are very specific to the insects they attack; they do not infect animals or plants. These fungi are used as biological insecticides, for example, the fungus *Beauveria*

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bassiana is a pesticide being tested as a possible biological control agent for the recent spread of emerald ash borer which attacks ash trees.

- **Farming :** The mycorrhizal relationship between fungi and plant roots is essential for the productivity of farm land. Without the fungal partner in root systems, 80–90 per cent of trees and grasses would not survive. Mycorrhizal fungal inoculants are available as soil additives from gardening supply stores and are promoted by the supporters of organic agriculture.
- **Food :** Fungi figure prominently in the human diet. Morels, shiitake mushrooms, chanterelles and truffles are considered delicacies. The meadow mushroom, *Agaricus campestris*, appears in many dishes. Moulds of the genus *is Penicillium* ripen many cheeses. Morel mushroom, an ascomycete, much appreciated for its delicate taste.
- In France, at the caves of Roquefort, wheels of a sheeps milk cheese are stacked to capture the moulds responsible for the blue veins and pungent taste of the cheese.
- **Fermentation :** The cereal grains are powdered and then fermented to produce beer. Some fruits are also fermented to produce wine, an ancient art. Ancient humans acquired wild yeasts from the environment to ferment sugars into CO_2 and ethanol under anaerobic conditions. Louis Pasteur was instrumental in developing a reliable strain of brewer's yeast, *Saccharomyces cerevisiae*, for the French brewing industry in the late 1850s.
- *Saccharomyces cerevisiae*, also known as baker's yeast, is also an important ingredient in bread, a food that has been considered a staple of human life for thousands of years.

Medicine : Many secondary metabolites of fungi are of great commercial importance. Fungi naturally produce antibiotics to kill or inhibit the growth of bacteria, limiting their competition in the natural environment. Important antibiotics are as follows :

- penicillin and cephalosporins can be isolated from fungi.
- the immuno suppressant drug cyclosporine that reduces the risk of rejection after organ transplant.
- Psilocybin is a compound found in fungi such as *Psilocybe semilanceata* and *Gymnopilus junonius*, has been used for hallucinogenic properties.
- **Model research organisms :** Many advances in modern genetics have been achieved by the use of the red bread mould *Neurospora crassa*. Additionally, many important genes originally discovered in *S. cerevisiae* served as a starting point in discovering analogous human genes.

Yeast cell as a eukaryotic organism produces and modifies proteins in a manner similar to human cells, as opposed to the bacterium Escherichia coli, which lacks the internal membrane structures and enzymes to tag proteins for export. This has made yeast a much better organism for use in recombinant DNA technology experiments. It also led to the development of YAC (Yeast Artificial chromosome).

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Chapter 14

ENVIRONMENT AND ECOLOGY

Environment and its biotic and abiotic components, adaptation in plants, adaptation in animals, types of nutrient cycles and their importance, succession: primary and secondary, bio-geographical distribution of life in India, types of biological interactions and wild life and practices of conservation.

- **Habitat :** The dwelling place of an organism in an ecosystem is called its habitat. It also refers to the place which is occupied by the entire biological community. In the habitat, an organism interacts both with its abiotic environment and biotic environment.
- **Biotic interaction :** It is the interaction of an organism with the other members of community. It can be intraspecific or interspecific competition.
- **Intraspecific competition :** The competition between the members of the same species such as for food and living place.
- **Interspecific competition :** The competition in the members of two or more different species occupying the same habitat such as for sunlight and water among plants.

BIOLOGY

Environment and Abiotic factors

- **Abiotic factors :** These factors may seem non-influential but are of indispensable significance such as temperature, annual precipitation , light , edaphic factors, *i.e.* type of soil, etc. These factors determine the type of flora and fauna that can survive successfully in a given habitat.
- **Temperature :** It is the most important of all the abiotic factors as on the earth it ranges from sub-zero temperature of polar regions or at very high altitudes to 50^0C or above of tropical deserts in summer. It affects both the physiological functioning and geographical distribution of organisms. e.g. exposure to cold enhances seed germination and also induces flowering in some plants.
- **Temperature and life zones :** The varying temperatures have created different life zones on the earth. These include tropical, sub-tropical, temperate, arctic and alpine. A very high or low temperature causes an immediate death of poikilotherms than of homotherms.
- **Poikilotherms v/s Homotherms :** Poikilotherm ectotherms animals, also called cold-blooded animals, are animals which adjust the body temperature with environment such as insects, fish and amphibians. They can tolerate and survive in a wide but narrow range of temperature. They lack any internal mechanism of thermoregulation (homeostasis). Homeotherms or Endotherms, also called warm-blooded animals. e.g. birds and mammals have

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a specific body temperature which they maintain with the help of internal thermoregulatory mechanisms. This involves sweating in summer, shivering in winter or presence of thick subcutaneous layer of fats underneath the skin like blubber in whales adapted for living in cold Arctic oceans.

- **Annual precipitation :** The availability of water is the second most important factor that influences the life on the earth. The organisms living in different living zones meet their water requirements differently irrespective of whether they are plant or animals, *i.e.* xerophytic, mesophytic or hydrophytic in habitat. The percentage availability of water in a living zone is directly or indirectly dependent on the annual precipitation that not only determines the volume of available surface water but also recharges the underground water table for use.
- **Sunlight :** The green plants are the primary producers as they can manufacture their own food by photosynthesis. It is a metabolic process that entirely depends on the availability of sunlight. The light also plays role in plant movements, germination of photoblastic seeds like that of lettuce, photoperiodism and daily rhythms in animals.
- **Daily rhythm in animals :** Animals show a great variation in their daily rhythm being nocturnal (night active) , diurnal (day active), vespersal (active at sunset like rabbits) or auroral (active at dawn like babalcus).
- **Light zones in deep waters of lakes or oceans :** There is light zonation in deep water in four zones. These are
  - (i) **Littoral zone :** It is the shallow water zone of the coastal region in which the light manages to pass and reach the bottom. Hence, producers occur throughout in littorel zone.
  - (ii) **Limentic zone :** It is an open water zone in which the light reduces with the increasing depth. It shows the presence of both producers and consumers.
  - (iii) **Profoundal zone :** It is also called as aphotic zone is the deep-water zone below the photic zone but above the bottom zone. It is perpetually dark characterized by the presence of consumers only.
  - (iv) **Benthoic zone :** It is the bottom zone of perpetual darkness characterized by the presence of consumers and decomposers. Most of the animals in this zone are blind.

Soil, its formation and types :

- **Soil:** In the words of Buckman and Brady," Soil is a dynamic natural body, on the earth's surface in which plants grow, is composed of minerals, organic matter and living organisms."
- **Pedology :** It is the science that deals with the study of soil. It makes up one of the ecological factors called edaphic factor. Physically, it

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is made up of different layers called horizons which further make up the soil profile.

- **Soil composition:** Soil has five components- mineral matter, organic matter , soil water , soil air and soil organism. The average proportion of these components is as follows:

Mineral matter	40%	Organic matter	10%
Soil water	25%	Soil air	25%
Soil organisms	Variable		

- **Soil texture :** It refers to the physical structure of soil due to the size, proportion and arrangement of its constituents. Three main types of soil textures are sandy, clayey and loam based on the three types of particles present in soil.
- **Sandy soil :** It contains 80% or more of sand. It is porous, moderate in mineral nutrients but loose with very low water holding capacity.
- **Clayey soil :** It has 40-50% of clay, the rest being mostly silt. It is good in mineral nutrients but poor in aeration and with closely packed clay particles. It makes root growth difficult. It has immense water holding capacity. or almost water porosity. However, clayey soil is a good potter's soil being excellent for use in making earthen pots.
- **Loamy soil :** It contains 20% clay, 40% sand and the rest of silt. This appropriate mixture of different particles makes it the best for plant growth being rich in mineral nutrients with good water holding capacity and necessary soil aeration for optimum root growth.

Weathering of rocks : It stands for the disintegration or natural breaking of rocks to form soil. There are a number of factors that contribute to weathering such as:

- Climatic and physical factors like change in temperature , blowing wind or flowing water, etc.
- Chemical weathering caused by hydration, oxidation, reduction, carbonation, etc.
- Biological weathering caused by pioneer community of lichens and plants or animals growing or living in rock cervices.

Environment and its components

- An environment has two major components, biotic and abiotic component. Each of these is incomplete without the other because of their interdependence.

Ecology : Ecology is the branch of biology that deals with the interactions between organisms and their environment.

- Biotic components include herbivores, carnivores and omnivores along with detrivores and decomposers such as some saprophytic fungi and bacteria.
- **Detritivores :** The organisms which feed on dead decaying organic matter both of plant and animal origin to form humus like earthworm are called detritivores.

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- **Saprophytes :** These are also known as Natural cleaners of the environment. Saprophytes like some saprophytic fungi and bacteria decompose the dead organic materials.
- **Ecosystem :** The structural and functional unit of environment.

  Ecosystem is a part of nature where there is the interaction of living organisms with eachother and the surrounding physical environment.

  Sir Arthur Tansley had first used the word ecosystem to describe the inter-relationship between bioitc and abiotic components of the environment. From a drop of pond water to an ocean is called an ecosystem.
- **Types of ecosystems :** The types of ecosystem depend primarily on the existing abiotic conditions in an ecosystem, *i.e.* xerophytic, aquatic, mesophytic, Arctic, *etc.* The relationships vary from place to place depending on the habitat primarily affected by the prevailing abiotic conditions. This has also helped divide the earth into different bio-geographical areas such as tropical rainforests, savannah, deserts, etc.
- **Anthropogenic ecosystem :** An artificially man-made ecosystem is an anthropogenic ecosystem such as a fish aquarium, a city garden, etc.
- **Food chain and food web :** The two represent the inter-relation between biotic components in an ecosystem.
- **Food chain :** The transfer of energy from one trophic level to the next trophic level is known as food chain. A food chain can be a grazing or detritus food chain.
- **Grazing vs detritus food chain :** In a detritus food chain, the first trophic level is occupied by saprophytes , the feeder of the dead (decaying organisms), while in a grazing food chain, it is occupied by green plants.
- **Food web :** It represents the interconnected network of different food chains in an ecosystem. It provides stability to an ecosystem. However, both the food chain and the food web involve the transmission of both matter and energy from one trophic level to the next. Both matter and energy decline with the succeeding number of trophic levels except of the bio-magnification.
- In both food chain and food web, regular input of energy is necessary for their sustenance and the green plants act as tranducers.
- **Bio-magnification :** Also called bioaccumulation, it involves the accumulation of non-biodegradable substances with the succeeding trophic levels. If an aquatic bird is compared for the presence of non-biodegradable chemical with respect to fishes it feeds on, the bird will show a higher percentage of the chemical than fish.

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- **Reasons for the ban on use of DDT and other pesticides :** The biomagnifications of non-biodegradable chemicals have led to the ban on the use of insecticides. It was observed that the aquatic birds feeding on fish living in DDT-contaminated water had started laying shell-less eggs that, started decimating their population, hence, to protect those bird's population, the ban was instituted on the DDT use. The same was observed in case of mercury contaminating the water that led the people of coastal areas feeding on fish to suffer from Minmata disease caused by accumulating mercury in their bodies.
- **Ecological pyramids :** A graphical representation in pyramidal form of the trophic structures is the ecological pyriamid based on factors such as the number of organisms at a trophic level , their biomass or total amount of energy transferred from one trophic level to the next.
- A pyramid of number and biomass can be inverted or upright, but the pyramid of energy is always upright from broad base to the pointed edge.

  They are of three types :

  1. Pyramid of number 2. Pyramid of biomass 3. Pyramid of energy.
- **Assimilation efficiency :** It refers to the percentage of food energy assimilated for body-building to the total ingested food by an organism.
- **Ecological succession :** It refers to a phenomenon or process by which an ecological community undergoes more or less orderly and predictable changes following a disturbance or the initial colonization of a new habitat. Succession may be initiated either by the formation of a new, unoccupied habitat, such as from a lava flow or a severe landslide, or by some form of disturbance of a community, such as from a fire, severe windthrow or logging. Ecological succession refers to change in the species composition over a long period in a particular habitat.
- **Primary and secondary succession :** Succession that begins in new habitats, uninfluenced by pre-existing communities, is called primary succession, whereas succession that follows the disruption of a pre-existing community is called secondary succession. Secondary succession is much faster than primary succession that initiates with lichens in xeric conditions and phytoplankton in aquatic conditions.

Nutrient cycles

Carbon, Oxygen and Nitrogen along with water are the most important links of nutrient cycle. Each component has an independent cycle due to which the complete ecological system is balanced. These cycles are also called as bio-geochemical cycles wherein bio stands for life and geo stands for earth.

- **Carbon cycle :** It begins with photosynthesis which combines sunlight, carbon dioxide from air and hydrogen from water to form carbohydrates. The food thus prepared is either used by plants

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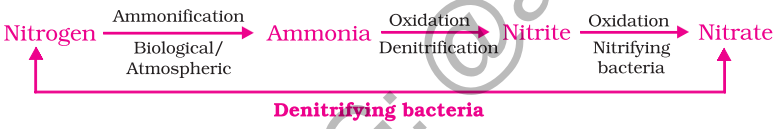
for growth or stored for energy. When animals eat plants, the nutrients in the plants get digested and carbon is released through exhalation or respiration. Carbon is again released back into the atmosphere when the living organisms die as they decompose again to form carbon dioxide. The combustion of fossil fuels and decomposition of carbonates and bicarbonates also add carbon dioxide into atmosphere from where it is reused in their formation such as the shells of molluscs and birds.

- **Nitrogen cycle :** Nitrogen is an important element of ecosystem but organisms except a few cannot use nitrogen directly. This is where the nitrogen fixing bacteria help by converting nitrogen into a usable form which can be absorbed by plants. When the nitrogen is fixed, it is available in the form of nitrates and nitrites which can be easily absorbed by plants as nutrients. Once it gets converted into food, it is eaten by animals which are returned back to the soil in the form of faeces and decomposed bodies of animals and plants. Also, there are denitrifying bacteria which balance the nitrogen level in the soil and, if found to be in excess, convert the nitrogen compounds into nitrogen and release it back into the atmosphere.



- **Oxygen cycle :** Oxygen is the main component of life on the earth. The earth's atmosphere consists of 21 per cent of oxygen. During photosynthesis, oxygen is released as a byproduct of plants while during respiration oxygen is taken in and water is released. Water is again absorbed by plants and the process starts all over again.
- **Water cycle :** The cycle starts when water evaporates due to heat energy from sunlight and becomes water vapour. The water vapour is responsible for cloud formation and rain or other forms of precipitation, *i.e.* hail, snow, etc. Hence, in these forms water returns back and assimilates in ground, rivers, seas, streams, ponds, lakes and oceans. This water is again absorbed by plants and released in the atmosphere later through transpiration and photosynthesis.

Forest ecosystem

- A forest ecosystem is a natural woodland unit consisting of all plants, animals and micro-organisms (biotic components) in that area functioning together with all of the non-living physical (abiotic) factors of the environment.
- **Structure of Forest Ecosystems :** Different organisms co-exist in forests. These organisms interact with one another and their surroundings. Each organism has a role in sustaining the ecosystem. Some provide food while others provide shelter or control populations through predation.

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- All the inhabitants of a forest have further been classified into the following :
- **Producers :** All living organisms intake energy to survive. In a forest ecosystem, trees and other green plants get their energy from sunlight. They produce their own food, in the form of carbohydrates. Hence, they are called the primary producers. Photosynthesis is the basic chemical reaction that allows plants to produce their own food.
- **Consumers :** Animals cannot produce their own food. They must consume food for energy they need to survive. All animals, including mammals, insects and birds, are called consumers. They directly or indirectly rely on plants as food sources.
- **Primary consumers :** They only eat plants and are referred to as herbivores, e.g., cow and deer.
- **Secondary consumers :** They are referred to as carnivores and feed on herbivores, e.g., lion.
- **Tertiary consumers :** They are carnivores that feed on other carnivores, e.g., polar bear, lion, eagle and hawk.
- **Omnivores :** These are animals that eat both plant and animal matter, e.g., humans, bears.
- **Decomposers :** Leaves and old branches fall onto the forest floor as trees grow. Eventually all plants and animals die. So what happens to all of these dead plant and animal materials? These materials are decomposed by worms, microbes, fungi, ants and other bugs.
- Decomposers break organic waste into the inorganic smallest primary elements to be used again. Hence, they are important in sustaining the nutrient cycle of ecosystems.

Types of forest ecosystems

- The amount of rainfall and prevailing temperature conditions in an area determines types of forest. If there is enough rain to support trees, then a forest usually develops otherwise, the region remains as a grassland.
- **Temperate Forest Ecosystem :** Temperate forests are in regions where the climate changes a lot from summer to winter.
- **Tropical Rainforests :** These forests are in regions where the climate stays constant all year-long.
- **Temperate forests :** These forests are almost always made of two types of trees:
- **Deciduous trees :** These are trees that lose their leaves in winter. These forests are found in the eastern slope of Western ghats and huge stretches of northern parts of India, in plains and peninsular India. e.g. Sal, teak, tendu, Khair etc.
- **Evergreen trees :** These are trees that remain green all year- long, like pine trees.

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- **Evergreen Rainforests :** These are found in the Assam Valley, the foothills of the eastern Himalayas and the lower parts of the Naga Hills, Meghalaya, Mizoram and Manipur where the rain-fall exceeds 2300 mm per annum. They are also found in the Andaman & Nicobar Islands and the Western Ghats.
- **Temperate Rainforests :** These are found only in California, Oregon and Washington in the United States. These forests have the tallest trees in the world. Redwoods and sequoias are the tallest trees of the world.
- **Tropical Rainforest Ecosystem :** This special ecosystem is homes to thousands of species of animals and plants. These rainforests not only have densely packed plants, but also are full of tall trees that form a ceiling from the sun above. This ceiling keeps smaller plants stunted. Areas where sunlight can reach the surface are full of interesting plants.
- **Vertical stratification :** In a forest, it refers to the natural arrangement of trees according to their heights. Neotropics: It refers to the famous Amazon jungle located in Brazil, in South America. Other large blocks of such forests are also found in Central and West Africa.
- **Tropical rainforest of amazon and fauna :** The most feared and well-known spider in the world resides in these jungles along with army ants, just one species of the ant in the rainforest and beautiful butterflies which fill these forests. These forests are also home to many snakes, the reptiles. The two dominant snake families found in these forests are Mamba and Anaconda, whose representative members are known to wrap themselves around their prey and squeeze, rather than inject poison. Anacondas swallow their prey whole and sleep while the food is digesting.
- **Chameleons :** These are interesting lizards that can change colour to enable them to blend in with their surroundings these are the inhabitants of these forests.
- Birds like kiwi and other birds aren't the only creatures that fly through these rainforests. The harmless fruit bat and the unique flying squirrel are the well-known inhabitants of these tropical rainforests. The Indian flying fox is one of the largest bats in the world. Its wings can spread out to 5 feet in width. Blood-sucking vampire bats live in the Amazon jungle in South America.
- **Taiga or boreal forests :** These include the contignous green belt of conifer and deciduous trees that encircle a large portion of the Northern Hemisphere. They are important as the "great lung" of North America. This ecosystem houses the largest and smallest mammal species (wood bison & pygmy shrews) of the North American continent with woodland caribou and lynx, whooping cranes and wood bison, northern owls, woodpeckers with three rather than four toes and colourful wood warblers.

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- **Tundra :** It is a type of biome where the tree growth is hindered by low temperatures and short growing season. There are three types of tundra: Arctic tundra, alpine tundra and Antarctic tundra. In tundra, the vegetation is composed of dwarf shrubs, sedges and grasses, mosses and lichens. Scattered trees grow in some tundra regions.
- **Tree line or timberline :** It refers to the ecotone (or ecological boundary region) between the tundra and the forest. It also refers to the altitude upto which the trees exist.

India's coastal and marine ecosystems

- These include a wide range of mangroves, coral reefs, sea grasses, salt marshes, mud flats, estuaries, lagoons and unique flora and fuana.
- **Sundarbans :** It is the largest delta in the world. It includes the area shared between India and Bangladesh. It is the largest contiguous mangrove in the world. India also has major stocks of corals, fish, marine mammals, reptiles and turtles, sea grass meadows and abundant sea weeds.
- **Mangroves in India :** They cover approximately 3,15,000 hectare-confined area mainly along the east (Odisha and West Bengal) coast and Andaman and Nicobar Islands. However, presently they are known to undergo degradation because of indiscriminate cutting, reclamation for agriculture and urbanization, fuel and overgrazing by domestic cattle.
- **Corals in Indian coasts :** Coral reefs are found in the Palk Bay, Gulf of Mannar, Gulf of Kutch, central west-coast of India, Lakshadweep and Andaman and Nicobar islands. A total of 50 genera and 13 sub-genera of reef-building corals are known to occur in Indian reefs representing more than half of those recorded from all over the world.
- **India's marine sector :** India has a long coastline of more than 7500 km. Its marine resources are spread over in the Indian Ocean, Arabian Sea and the Bay of Bengal. The exclusive economic zone (EEZ) of the country has an area of 2.02 million sq km comprising 0.86 million sq km on the west coast, 0.56 million sq km on the east coast and 0.6 million sq km around the Andaman and Nicobar the islands.
  - The east coast supports activities such as agriculture and aquaculture.
  - The west coast with a number of industries along with tourism like in Goa and Kerala.

Causes of decline in India's coastal and marine environments :
The coastal and marine environments are threatened by:

- the lack of integrated development planning, especially when there is the large concentration of towns, petrochemical complexes and industries along India's coasts.

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- addition of untreated sewage and industrial effluents into coastal waters. Only 9% of wastewater from India's coastal towns is treated before entering coastal waters.
- non-availability of the proper sources of livelihood. It has put large numbers of coastal people to remain dependent on natural resources for their livelihoods.
- adoption of traditional methods of fishing which adds to environmental degradation and over exploitation.

Environment and Plant adaptations

All organisms try to cope with the environment in which they live. Some regulate their physiological functioning internally (homoeostasis) while others try but only up to a certain narrow limit. The former, such as homeotherms, are called 'regulate' and the later are called 'conform' such as poikilotherms. The homotherms have evolved ability to regulate but only for a limited period of time beyond which, they have developed and tend to develop necessary adaptations.

- **Adaptation :** refers morphological, physiological or behavioural changes in an organism to survive successfully and interbreed in a given habitat. Both plants and animals show different types of adaptations depending on their environmental demands.
- **Plant stratification and light :** It refers to the vertical arrangement of plants depending on their heights based on light requirements forming different strata. The plants with more light intensity requirements grow taller than others with less light requirements like heliophytes and schiophytes.
- **Heliophytes v/s Sciophytes :** The plants adapted to bright light are called heliophytes compared to plants adapted to growing well in shady areas are known as sciophytes.
- The heliophytes growing in bright light have thick cuticles, hairy leaves, developed layers of palisade cells with a large number of chloroplasts, sunken stomata and deep well-developed root system compared to schiophytes who have thin cuticles, thin palisade layers of cells with less number of chloroplasts, stomata on leaf surfaces and moderate to poorly developed root system.
- **Plants with fulfilment of water requirements :** There are basically three broad categories of plants based on the water requirements and their fulfilment. These are xerophytes , hydrophytes and mesophytes.
- **Xerophytes :** These are plants adapted to water scarcity or hot desert conditions. They have further been classified as:
- **Drought escapers :** also called ephemerals, they live for a short time only during the rainy season such as *Tribulus terresteris* and *Euphorbia prostrate.*

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- **Drought evaders :** They have short life-span and manage to survive even after rains for a few months by improving water absorption and reducing transpiration such as *Echinopus echinatus* and *Solanum surattense*.
- **Drought resistants :** also called succulents, they have fleshy body parts like stem in *Opuntia* and *Euphorbia* or fleshy roots in *Asparagus* to store water. The fleshy photosynthetic stems are called phyllocladodes(indefinite growth) and cladodes(definite growth). They all possess sunken stomata which open only at night and in photosynthesis for the reduction of carbon dioxide to produce sugar use CAM (Crassulacean Acid Metabolism) cycle.
- **Drought endurers :** These plants are capable of enduring drought conditions with presence of sunken stomata, smaller shoot system but an extensive root system. In some of them like grasses , the leaves fold during dry weather or others have leaves with spines or prickles such as *Acacia*. They also possess chaperonins, the heat shock proteins, thick cuticles with waxy covering and use C4 cycle for the reduction of carbon dioxide to produce sugar.
- **Phreatophytes :** These are trees found in deserts whose roots grow to the depth of water table to absorb water such as *Tamarix* and *Prosopis*.
- **Hydrophytes :** These plants grow in aquatic habitat. They can be submerged, suspended, free-floating, leaves anchored or emergent hydrophytes. These plants are characterized by the presence of mucilage, roots either absent or if present without root hair, poorly developed xylem for water transport and presence of aerenchyma in plant parts like stem and leaves. Aerenchyma is a type of parenchyma whose cells are filled with air cavities to make them soft and spongy to float in or on water surface they also provide buoyancy to the plant. Leaves, if present, are waxy with large stomata only on upper leaf surface. Ranunculus aquatilis is an aquatic plant which has two types of leaves, the fragmented submerged leaves and broad non-fragmented air-borne leaves.
- **Halophytes :** These plants are also called saline plants as they grow in the saline habitat of coastal marshes, mangroves, coastal dunes and saline soil such as *Atriplex* , *Spartina* , *Sueda* , etc. They have succulent types of leaves and stems having thick cuticles and sunken stomata to store water and mucilage while some secrete salts using salt glands.
- **Mangrove plants :** These plants are known to possess pneumatophores, the breathing roots, found in plants such as Rhizophora. These roots are negatively geoptropic as they emerge out of water surface with a pore in the centre or lenticels for gases

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exchange, necessary for root cells. Mangrove plants are also known to exhibit vivipary, i.e. the seed germinates while still attached to the parental plant. It is only the radicle that grows into water while the plumule remains above water attached to the mother plant.

- **Plants and oligotrophic soils :** These are soils poor in nutrients such as in some areas of tropical zone of rainforests. Plants growing in these soils such as *Pine, Oak, Eucalyptus, etc.* develop mycorrhizae, the mutualistic relationship with fungi for the absorption of water and minerals. The mycorrhizae can be ectomycorrhiza or endomycorrhiza.

Environment And Animal adaptations

- Animals show adaptation for different reasons such as for feeding, escaping from unfavourable conditions, mating or protection from predators.
- **Migration :** The animal migration can be long distance , short distance, periodic or daily.
- Long-distance migration is exhibited by the Arctic tern that migrates from one pole to another every year.
- Short-distance migration is shown by birds and fish such as whales. They migrate from the Arctic Ocean to warmer areas for food.
- Periodic migration is shown by locusts in their search of rich-feeding grounds upon hatching.
- **Camouflage:** It refers to the ability of an animal to blend with colour or form of the surroundings such as in case of a stick insect, leaf-like grasshopper, leaf insect or praying mantis.
- **Mimicry :** It refers to the resemblances of a species with another as means of protection against predators . The mimcry can be Batesian or Mullerian.
- In Batesian mimicry, the insect Vicroy butterfly mimics the toxic Monarch fly.
- In Mullerian mimicry, the insect makes ferocious mimic for mutual benefit like Monarch butterfly and Queen butterfly.
- **Hibernation and aestivation :** The winter sleep or summer sleep provides protection from unfavourable climatic conditions of cold winter or hot summer days.
- **Hibernation** refers to winter sleep in which an animal lives a passive life hiding in caves like the polar bear or at the bottom of water reservoir such as ponds like frogs.
- **Aestivation** refers to summer sleep in which mostly xerophytic animals hide them in burrows or at some shady place during day to protect them from the scorching heat of the sun. It's at night they come out like some lizards and snakes, etc.

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- **Diapause :** It is a state of suspended development as observed in zooplankton and larvae of pink cotton bollworm which enter in diapause in winter months to hatch in summer.
- **Cold hardiness :** It refers to the development of protection against extremely cold conditions with the deposition of anti-freeze proteins and glycerol in body fluids such as in Ice fish or Antarctic fish.
- **Adaptation in desert animals :** These animals like a camel or kangaroo rat are well adapted to live in the hot desert conditions of water scarcity with thick coat, almost no sweating, dry faeces, concentrated urine and ability to survive on metabolic water produced during respiration. Kangaroo rat is the only animal which can survive without water.
- **Allen's rule :** The rule describes the relation in the size of body organs with climatic conditions. According to the rule, animals living in cold climates have shorter limbs, ears and tails than their counterparts living in warm conditions to minimize the heat loss from their bodies.

Biodiversity

- **Biodiversity :** Biodiversity refers to the totality of genes, species and ecosystems in a region. The term is used for describing diversity at all levels of biological organization from macromolecules inside a cell to biomes. It was first applied by sociobiologist Edward Wilson.
- **Forests :** In a broad sense, forests are considered as the hot spots of biodiversity.
- **Species diversity :** It refers to the richness of a species in a geographical area. It can be alpha , beta or gamma.
- **Alpha diversity :** The species diversity with maximum percentage of competitiveness and adjustments is alpha diversity, as they share same habitat or community.
- **Gamma diversity :** The species diversity found established in a large geographical area hence, having the least competition that is capable of facing the period of stress for a longer period of time is gamma diversity.
- **Beta diversity :** It has the species diversity between alpha and gamma and, hence, moderate competition and adjustment among organisms. It refers to between community diversity.
- **Evil quartet :** It describes the four main human induced causes of the loss of biodiversity. It includes the fragmentation of a habitat, invasion of alien species, over harvesting and mass extinction. Presently, ecologists are of the view that so far the earth has faced five mass extinctions because of natural causes but the sixth extinction, if happened, would purely be anthropogenic looking at the alarming rate of the extinction of species because of human inter ferance and activities.

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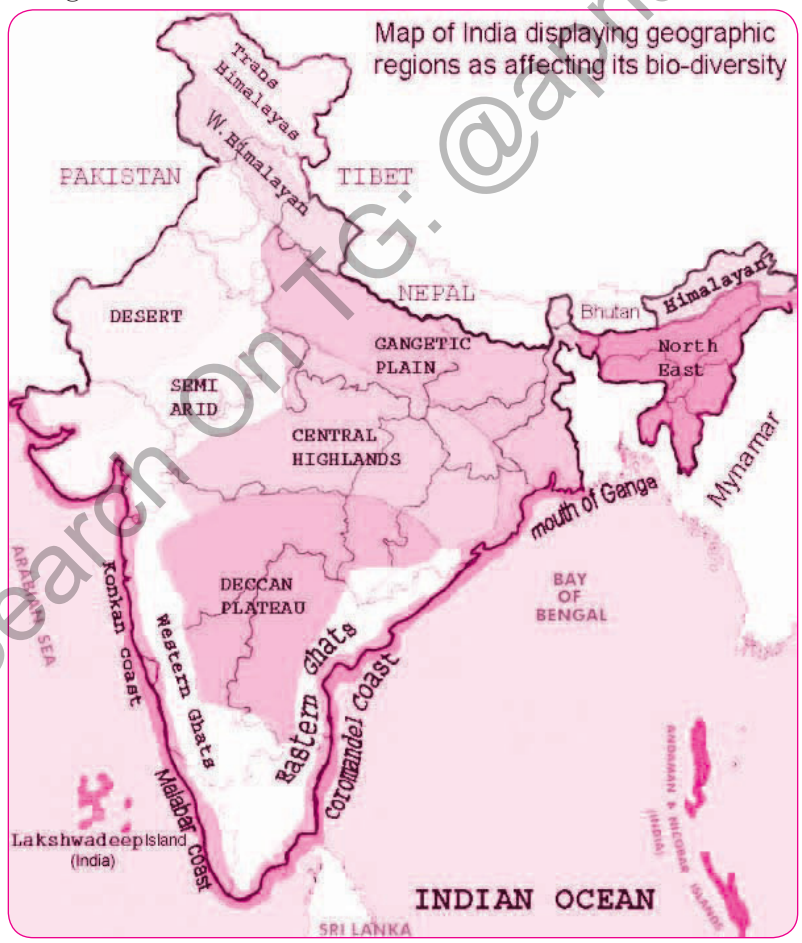
Value of biodiversity of plants : In any area, the existing biodiversity has its own value as about:

- 80,000 edible plants and about 9% of present day food crops have been domesticated from wild plants.
- 75% of the world's population depends on plants or plant extracts for drugs and medicines.
- plant wood and timber has been used as fuel and for making furniture for ages.
- 2%-4% of plants like tulsi, lotus , peepal ,etc are considered as the holy sacred plants.
- **India and biodiversity :** India is one of the twelve mega diversity regions of the world with about 7.7% of genetic resources. Wild life Institution of India has divided the country into ten bio-geographical regions as shown below.



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S. No.	Biogeographical region	Biotic province
1.	Trans-Himalayas	Upper reaches of the Himalayas.
2.	Himalayas	North-West Himalayas, West, Central and East Himalayas
3.	Desert	Kutchh, Thar and Ladakh
4.	Semi-arid	Central India, Gujarat Rajwara
5.	Western Ghats	Western coast, Western Ghats Mountains
6.	Deccan Peninsula	Deccan Plateau, South-Central plateau, Eastern Plateau, Chotta Nagpur, Central High Lands
7.	Gangetic Plains	Upper and Lower Gangetic plains,
8.	North East India	Brahmputra Valley, North Eastern Hills
9.	Islands	Andaman Nicobar Islands, Lakshdweep Islands
10.	Coasts	East and West coast

Indian Bio-geographical habitats

Deccan peninsula : The largest region that occupies 42% of land mass.

Western Ghats : The most biodiversity regions of India with a large number of endemic amphibian population and wild relatives of cultivated plants like Citrus, Mango, Pepper, etc.

Trans-Himalayas : The cold region with sparse vegetation but with a rich community of goats, sheep and snow leopards.

Islands : These are rich in evergreen forests

Coasts : These are known for mangrove vegetation.

- **Causes for the loss of biodiversity :** There are a number of causes that have combined together to adversely affect the existence of the present biodiversity. Some of these causes include:
- **Fragmentation :** The fragmentation of the natural areas has led to habitat loss. Among all, the animals which require large territories like birds and mammals are the most affected along with migratory animals. They end up going astray to be hunted or killed. Its prime cause is an increase in human population over the last few decades at an alarming rate. It not only requires land for residential areas but also there is requirement for establishing industries to satisfy the increasing human needs.
- **Over-exploitation :** The excessive exploitation of a species for human need has led to the extinct of several species such as of dodo bird, passenger pigeon, etc. Similarly, the overlogging of trees is threatening the extinction of some trees.

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Invasion of alien species : The invasion of alien species whether voluntarily or involuntarily, always threatens the existence of the native species such as

- introduction of Water Hyacinth (*Echhornia crassipes*), now called Terror of Bengal to check water pollution, is clogging the waterways leading to the death of aquatic plants and animals.
- introduction of Nile perch, predator fish in Lake Victoria in South Africa, has led to the extinction of the native Cichlid fish.
- introduction of *Partherium hysteophorus* has led to the death of many of the herbs and shrubs in India.
- introduction of only a dozen of rabbits has now become a cause of disaster to farmers.
- **Pollution :** The pollution of different forms particularly water , air and land is threatening the extinction of many of the aquatic and terrestrial species of plants and animals. The recent example is the disappearance of the bird called 'Sparrow' from the areas of Delhi and U.P.
- **Monoculture :** It refers to the mode of agriculture or forestry where only a specific of economical value is reared and managed for commercial gains. This, however, led to the extinction of the other species in spite of their biological importance in maintaining the ecological balance.

Types of biological interactions

In the natural world, no organism exists in absolute isolation, and thus every organism must interact with the environment and other organisms. These interactions are called biological interactions. These interactions include positive or negative interactions.

(i) **Amensalism :** It is an interaction in which an organism inflicts harm to another organism without any costs or benefits received by itself such as cattle trampling the grass while walking on it. The presence of the grass causes negligible detrimental effects to the animal's hoof but the grass suffers from being crushed.

(ii) **Predation :** It is the ecological interaction in which a predator preys (kills) the host before feeding on its biomass. In general, it represents carnivory such as a tiger or leopard hunting a deer. Herbivory is also biologically a form of predation in which a herbivore feeds on a plant or plant parts.

- Animals have developed varied adaptive features to protect them selves from predators such as camouflage or mimicry. Similarly, plants have developed special features to protect themselves from herbivores such as thorns, spines or production of alkaloids, etc.

(iii) **Parasitism :** It is an antagonistic interaction in which one species benefits at the expense of another. The parasite can be endoparasite or ectoparasite. The endoparasite enters into the body of a host to

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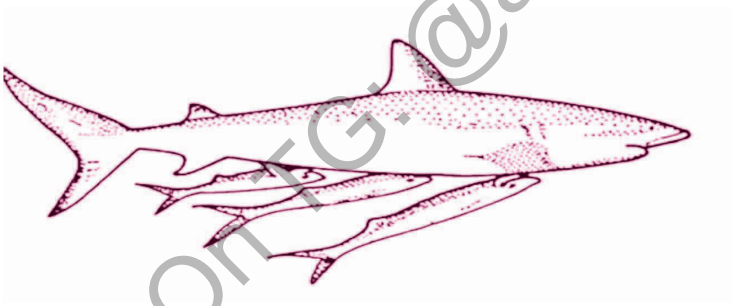
cause harm such as all infectious diseases causing microbes in humans while ectoparasites remain only on body surfaces to cause harm such as ticks, mites or cuscuta in plants.

- **Neutralism :** It describes the relationship between two species that interact but do not affect each other. It describes interactions where the health of one species has absolutely no effect whatsoever on that of the other. However, practically, no such interaction exists in Nature.

Positive effect Interaction

(i) **Commensalism :** It benefits one organism while the other organism remains neither benefited nor harmed. It occurs when one organism takes benefits by interacting with another organism by which the host organism is not affected. A good example is a remora (sucker fish) living with a shark. Remoras eat the leftover food from the shark. The shark is not affected in the process, as remoras eat only the leftover food of the shark, which does not deplete the shark's resources. Similar examples are expressed by epiphytic plants growing on bigger plants, jackals following a tiger on hunting spree.



Commensalism of shark and remora fish

(ii) **Mutualism :** Mutualism is an interaction between two or more species, where species derive a mutual benefit, for example pollination illustrates mutualism between flowering plants and their animal pollinators.

Mutualism may be classified in terms of the closeness of association, the closest being symbiosis, which is often confused with mutualism.

One or both species involved in the interaction may be obligate, *i.e.* cannot survive in the short or long term without the other species. Though mutualism has historically received less attention than other interactions such as predation yet it is a very important subject in ecology. Examples include cleaner fish, pollination and seed dispersal, gut fauna between a hermit crab and a sea anemone. Nitrogen fixation by bacteria in the root nodules of legumes is the other example of mutualism. Mutualism of algae and coelenterates in the coral reefs is a best example of obligate relationship.

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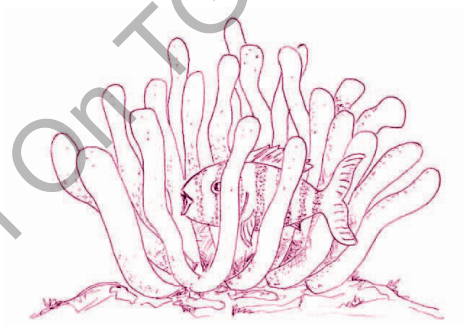
Mutualism

(iii) **Symbiosis :** Common clownfish (*Amphiprion ocellaris*) in their Red sea anemone (Heteractis magnifica) home. Both the fish and the anemone benefit from this relationship, a case of mutualistic symbiosis.



Symbiosis

It also describes various degrees of close relationship between the organisms of different species. The other examples include :

- lichens composed of 95% fungal partner and 5% of photosynthetic algal partner.
- a large percentage of herbivores have mutualistic gut bacterias that help them digest plant matter.
- Coral reefs are the result of mutualism between coral organisms and various types of algae that live inside them.
- mycorrhyzal fungi that help absorb water and extract minerals from the ground found in about 80 percent of higher plants.

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Wildlife and its conservation

India's rich biodiversity and unique wildlife are its greatest national treasures. As the country embarks on a programme of rapid development, India's wildlife, including charismatic species such as the tiger, elephant, rhino and their habitats are facig the constant threat of degradation and fragmentation. India's conservation efforts seek to secure long-term survival of India's wildlife and their habitats.

Conservation practices for wildlife : There are two forms of conservation practices adopted by the countries worldwide including India. These are :

In-Situ Conservation Practices : These practices involve the conservation of species in their natural habitats. It is considered to be the most appropriate way of conserving biodiversity in areas, so- called national parks, game reserves or sanctuaries and Biosphere reserves.

Ex-Situ Conservation Practices : These practices involve the preservation of the components of biological diversity outside their natural habitats. It involves zoos , botanical gardens and conservation of genetic resources, as well as wild and cultivated species and draws on a diverse body of techniques and facilities. Some of these include:

- Gene banks, e.g. seed banks, sperm and ova banks, field banks, cryopreservations
- In vitro plant tissue and microbial culture collections
- Captive breeding of animals and artificial propagation of plants, with possible reintroduction into wild
- **IUCN and Red Data Book :** IUCN (International Union for Conservation of Nature and Natural Resources) annually produces 8 red lists in Red Data Book enlisting the different extinct, endangered , vunerable and rare species for their appropriate conservation across the world.
- **WWF** (World wildlife fund) is an international organization which provides necessary funds required by a country for the conservation of a particular species of wildlife.
- **Protected Areas of India :** The total number of national parks, sanctuaries, etc. in existence today is:

	Number	Total Area (km2)
National Parks (NPs)	103	40500.13
Wildlife Sanctuaries (WLSs)	537	118005.30
Conservation Reserves (CRs)	67	2349.38
Community Reserves	26	46.9

At present, India is involved in the conservation of tigers, elephant populations and their habtiats in Terai Arc Landscape, North Bank Landscape, Kaziranga Karbi Anglong Landscape and Western Ghats Nilgiri Landscape, rhinos in North Bank Landscape, Kaziranga Karbi Anglong Landscape and Terai Arc and in conserving the populations and habitats of red panda, snow leopard and nilgai.

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Chapter 15

POLLUTION : CAUSES AND EFFECTS

Pollution, types of pollution: air pollution, water pollution , soil pollution and noise pollution, their causes and control. Effects of increasing pollution on global environment and human health, i.e. global warming, depletion of ozone layer, acid rain and occupational diseases.

- **Pollution :** It refers to the addition of undesirable substances called pollutants in different forms of natural resources which adversely affect their quality, quantity or both quality and quantity.
- **Two principal causes of pollution :** The two principal underlying causes of different forms of pollution are an increase in human population at an alarming rate over the last few decades and an increase in industries at a rate faster than the above to fulfil the demands of basic resources along with the trend in living a luxurious life.

BIOLOGY

Types of pollution

The major types of pollution are listed below along with the particular pollutants related to each of them.

- **Air pollution :** It is caused by the release of gaseous chemicals and solid particulate matter (SPM) into the atmosphere. Common gaseous pollutants include carbon monoxide, sulphur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides produced by industries and motor vehicles. Particulate matter, fine dust etc.
- **Photochemical smog :** It is a kind of secondary pollutant which is formed due to ozone (O_3), peroxyacetyl nitrate (PAN) and nitrous oxides in presence of intense solar radiation. It is mainly found in metro cities due to high traffic congestion. It is also reffered as 'gray air'.
- **Water pollution :** It is caused by the discharge of waste water from commercial and industrial waste (intentionally or through spills) into surface waters; discharges of untreated domestic sewage, and chemical contaminants, such as chlorine, release of waste and contaminants into surface runoff (including urban runoff and agricultural runoff, which may contain chemical fertilizers and pesticides), waste disposal and leaching into ground water eutrophication and littering.
- **Soil pollution :** It refers to the soil contamination with chemicals released by spill or underground leaching. Among all the known causes, the most significant soil contaminants are hydrocarbons, heavy metals, intensive farming involving the use of agrochemicals such as herbicides, pesticides and chlorinated hydrocarbons.
- **Noise pollution :** It encompasses roadway noise, noise from disco theatres, aircraft noise, industrial noise. The intensity of sound measured in decibels . Humans maximum audible limit of 20KHz.

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- **Thermal pollution :** It is a temperature change in natural water-bodies caused by human influence, such as use of water as coolant in a power plant, water from boilers in steel industries, etc. The warm water added to natural water reservoirs not only harms aquatic life but also destroys the micro flora and micro fauna responsible for the natural replenishment of water.
- **Radioactive pollution :** It is caused by radioactive contamination, resulting from the 20th century activities in atomic physics, such as due t release of radioactive substances in air, water or ground because of activities and research in nuclear physics, nuclear power generation and nuclear weapons research, manufacture and deployment.
- **Visual pollution :** It refers to the presence of overhead power lines, motorway billboards, scarred landforms (as from strip mining) open storage of trash, municipal solid waste or space debris.
- **Littering and plastic pollution :** Littering involves throwing of inappropriate man-made objects, unremoved, on public and private properties while plastic pollution involves the careless disposal of plastic waste leading to its accumulation in the environment that adversely affects wildlife, wildlife habitat or humans.

Adverse effects of different forms of pollution :

Pollution has been found to be present widely in the environment. There are a number of increasing adverse effects of this such as:

- **Biomagnification,** also called bioaccumulation, describes situations where toxins (such as heavy metals) may pass through trophic levels, becoming exponentially more concentrated in the process. It's for the same reason one time well known insecticide DDT use was banned in the early 1980's.
- The runoff agrochemicals also promote accelerated eutrofication enforcing aquatic life to perish with the creation of BOD (Bichemical oxygen demand) and COD (Chemical oxygen demand). The BOD value is expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water. For water to be considered potable, it should not exceed 2parts per100,000 parts of oxygen. The normal unpolluted river water has the value in range of 2 to 8 parts per 100,000 parts of oxygen.
- Carbon dioxide emissions cause ocean acidification, the ongoing decrease in the pH of the Earth's oceans as CO_2 dissolved.

The major contributors to global warming include	
Water vapour :	36–70%
Carbon dioxide (CO_2) :	9–26%
Methane (CH_4) :	4–9%
Ozone (O_3) :	3–7%.

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- Clouds also affect the radiation balance through cloud forcings similar to greenhouse gases.
- All these together lead to global warming which affects ecosystems in many ways like the submerging of coastal areas, unpredictable changes in weather conditions across the world, melting of polar ice, etc. It has been realized the percentage concentration of CO_2 that was 0.03% in atmospheric air has risen to 0.04% or above in the last few decades.

Climate model projections summarized in the report indicated that during the 21st century the global surface temperature is likely to rise a further 0.3 to 1.7 °C (0.5 to 3.1 °F) for the lowest emissions scenario and 2.6 to 4.8 °C (4.7 to 8.6 °F) for the highest emissions scenario.

- **Contributors to carbon emission:** Fossil fuel burning has produced about three-quarters of the increase in CO_2 from human activities over the past 20 years. The rest of this increase is caused mostly by changes in land-use, particularly deforestation. Another significant non-fuel source of anthropogenic CO_2 emissions is the calcination of limestone for clinker production, a chemical process which releases CO_2. Estimates of global CO_2 emissions in 2011 from fossil fuel combustion, including cement production and gas flaring, were 34.8 billion tonnes (9.5 ± 0.5 PgC), an increase of 54% above emissions in 1990. Coal burning is responsible for 43% of the total emissions, oil 34%, gas 18%, cement 4.9% and gas flaring 0.7%.
- Nitrogen oxides are removed from the air by rain and fertilize land which can change the species composition of ecosystems.
- Smog and haze which can not only reduce the amount of sunlight received by plants to carry out photosynthesis and but also lead to the production of tropospheric ozone which damages plants.

Ozone as a bluish gas is considered as a chemical weed because on the earths surface it is toxic but high up in troposphere and stratosphere it is of great value in reducing the percentage of UV rays reaching the earth's surface.

- Depletion of ozone layer by released CFCs and oxides of nitrogen high up in atmosphere is threatening the existence of life on the earths surface. With the depletion of ozone layer whose thickness measured in Dobson unit has decreased, there is an increase in the percentage of UV rays reaching the earths surface. These rays are considered responsible for the increasing number of people suffering from snow blindness, cataract, skin cancer and immunodeficiency diseases along with a decline in crop production by 28%. Therefore after the discovery of ozone hole in 1975 by British team over South Antarctica , in 1976 Montreal Protocol urged for limiting the production and use of ozone- depleting substances and promoting the use of alternatives to CFCs.

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- Sulphur dioxide and nitrogen oxides cause acid rain which lowers the pH value of soil. Any pH value of rain water below 5.8 designates the rain water to be acidic. The acid rain affects not only the flora and fauna but also the commercial structures such as metallic bridges ,cables, statues and marble structures like the Taj Mahal which is suffering from what is called as 'Marble cancer'. So alos the 'Statue of Liberty' USA.
- The recent increased dissolution of acidic oxides in marine water has led the average marine water pH to go down from 8.2 to 8.1-8.0.
- Increasing percentage of soil erosion because of anthropogenic activities such as deforestation and natural causes like flash floods and winds is converting the fertile lands of the past into the barren lands or deserts of today.

Occupational diseases	
Disease	**Cause and effects**
Asbestosis	Asbestos miners and among those who work with friable asbestos insulation sheets.
Pneumoconiosis	Miners and people working in thermal power stations.
Silicosis	Among miners and quarrying and tunnel operators, exposure to silica dust.
Dermatitis	Among people working with common irritant. These include detergents, acids, alkalis, oils, organic solvents and reducing agents used for hairdressing, catering, printing, metal machining and motor vehicle repair and construction.
Computer vision syndrome	Among persons working in information technology industries for long hours.
Carpal tunnel syndrome	Among persons who work in the poultry industry and information technology.
Lead poisoning	It affects workers in many industries that process or employ lead or lead compounds such as in the manufacture of storage batteries, paints, etc.
Byssinosis	Among person working in raw cotton and textile industries.
Chimney sweeps' carcinoma (soot wart)	People engaged in the cleaning of chimneys, mostly common in olden days among the people of poor community.

- **Preventive measures** : These include avoidance of the irritant through its removal from the workplace or through technical shielding by the use of potent irritants in closed systems or automation, irritant replacement or removal and personal protection of workers.

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An individual's role in controlling pollution :

Every action or inaction of any person has an effect on the environment—be it good, neutral or negative. By becoming aware and doing the right thing, one chooses to be part of the solution. Here are some things which need to be done in checking pollution:

- Avoid smoking or don't throw your butts on the ground. Cigarette butts are not biodegradable and contain extremely toxic soluble chemicals. One butt thrown on the ground can remain for up to 25 years, leaking chemicals like arsenic, ammonia, acetone, benzene, cadmium, formaldehyde, lead and toluene into the environment. (Littoral pollution)
- Prefer driving an electric or a hybrid car or at least one that uses unleaded gasoline or CNG (Compressed Natural Gas).

CNG use as a fuel has an advantage over the use of gasoline because it has 1.4 times higher calorific value than gasoline and is also ecofriendly Because of its complete combustion , it does not produce any SPM or toxic gas.

- Keep your car in a good running condition with a catalytic convertor to avoid emissions. A three-way catalytic converter has three simultaneous tasks:
- Reduction of nitrogen oxides to nitrogen and oxygen:
  $2NO_x \rightarrow xO_2 + N_2$
- Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$
- Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water :
  $C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$
- Adopt the ion of the 3 Rs policy of solid waste management: reduce, reuse and recycle. Prefer using sustainable, reclaimed or recycled building materials.
- Prefer using the alternative sources of energy or power such as solar energy, hydroelectricity, etc.
- Prefer installing and using Ecosan toilets. These toilets widely used in Kerala do not use any water for flushing.
- Use and buy products that are eco-friendly or made with biodegradable materials. Avoid plastics.
- Promoting the exercises of reforestation and afforestation while preventing any practice that may directly or indirectly lead to deforestation such as in the use of furniture , paper, etc. Trees in forests clean the air, provide oxygen and beautify the surroundings.
- Encouraging the installation of Green Mufflers. These are the rows of trees planted on either side of a road to minimize both noise and air pollution.
- Say a big "NO" to agrochemicals like pesticides and GMOs (genetically modified organisms). Give preference to organic farming.
- Join and celebrate the Earth Day celebration on April 22nd every year.

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Chapter 16

AGRICULTURE & ANIMAL HUSBANDRY

Types of agriculture, steps involved in agricultural practices, nutrients requirements, fruits v/s vegetables, types of vegetables, soil types, common spices and plant parts, pests and their types, Genetically modified crops, weedicides, Ayurvedic Medicines and Herbs, Improved varieties of crops, animal husbandry, dairy farming and animals, pisiculture, poultry i.e. broilers and layers, apiculture and sericulture.

- **Agriculture :** It is the cultivation of animals, plants and fungi for food, fiber ,biofuel, medicinal plants and other products used to sustain and enhance human life. It is considered as the key development in the rise of sedentary human civilization, whereby farming of domesticated species created food surpluses that nurtured the development of civilizations. The study of agriculture is known as Agricultural Science.
- **Types of agriculture :** The agriculture based on the purpose and the practices involved has been classified in four types as listed below:
- **Pastoralism :** It involves managing domesticated animals. In nomadic pastoralism, herds of livestock are moved from place to place in search of pasture, fodder, and water. This type of farming is practiced in arid and semi-arid regions of Sahara, Central Asia and some parts of India.
- **Shifting cultivation :** It involves clearing a small area of forest by cutting and burning to develop land for agriculture. The land is restored for agriculture until the soil loses its fertility when it is abandoned. Another patch of land is selected and the process is repeated. This type of farming practice is also called Jhum cultivation. It is mostly practiced in areas with abundant rainfall where the forest regenerates quickly. This practice is used in Northeast India, Southeast Asia, and the Amazon Basin.
- **Subsistence farming :** It is practiced to satisfy family or local needs alone, with little left over for transport elsewhere. It is intensively practiced in Monsoon Asia and South-East Asia
- **Intensive farming :** It is practiced to grow crops for commercial purpose i.e., for selling. The main motive of the farmer is to make profit, with a low fallow ratio and a high use of inputs. This type of farming is mainly practiced in developed countries.
- **List of steps involved in farming :** The different steps in farming from crop selection to harvesting include:

Crop selection ⟶ Land preparation ⟶ Seed selection ⟶ Seed Sowing ⟶ Irrigation ⟶ Crop growth (Weeding, fertilizing, pest control ⟶ Harvesting

- **Crop Selection :** In crop selection a farmer looks into the cost involved, climate, quality of land available , market demand of the crop in intensive farming , etc.

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- **Land Preparation :** The farmer looks into effects of any disease from the previous cultivation and steps needed to minimize this impact, fertilizers needed to bring land to its normal fertility depending upon the previous crops and fertilizer used and the latest techniques for leveling the fields and their cost.
- **Seed Selection :** The farmer looks into the price and quantity needed per acre, suitability to particular area and climate, water requirement and resistance to diseases w.r.t. HYV.
- **Seed Sowing :** The famer finds appropriate time to sow the seed, best method distance and depth of the sowing of seed.
- **Irrigation :** The farmer needs to have proper information about critical time for irrigation ,amount of water to be given to the plants and frequency of irrigation.
- **Crop Growth :** The farmer for proper crop growth has to fertilize the soil with addition of single or mixed fertilizers and perform weeding. For this he needs to be aware of the type of fertilization and proper time, frequency and method for weeding.
- **Single fertilizers :** These fertilizers are source of anyone of the major nutrient i.e. nitrogen(N), potassium(K) or phosphorus(P). like urea.
- **Mixed fertilizers :** These fertilizers like ammonium phosphate are source of two or all the three major nutrients.
- He is also expected to be aware of pest and virus attacks, symptoms of such attacks, precautionary measures that can be taken in advance to avoid these attacks, immediate actions including pesticide to be used to kill pests and viruses, quantity of pesticide to be used per acre and the most effective method of application.
- **Harvesting :** The farmer needs to be aware of proper time and method for harvesting along with proper crop storage practice after harvesting.
- **Agriculture and climate :** It's obvious that in a sunny and hot climate crops need more water per day than in cloudy and cool climate. Hence, a farmer needs to be well aware of the prevailing climatic conditions in the area at a given time of the year. The average water requirement in different climatic zones is :

	Mean daily temperature		
Climatic zone	Low (less15°C)	Medium (15°C-25°C)	High (More than 25°C)
Desert / Arid	4 - 6 mm	7 – 8 mm	9 – 10 mm
Semi arid	4 - 5 mm	6 – 7 mm	8 – 9 mm
Sub-humid	3 - 4 mm	5 – 6 mm	7 – 8 mm
Humid	1 – 2 mm	3 – 4 mm	5 – 6 mm

- **Crop type and water requirements:** Plants differ in their water requirements. The table below list some of he crops with their water requirements.

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Crop	Water requirement (mm/total growing period)	Crop	Water requirement (mm/total growing period)
Barley/Oats/ Wheat	450-650	Cotton	700-1300
Bean	300 – 500	Maize	500-800
Cabbage	350 - 500	Onion	350-550
Citrus	900 - 1200	Pea	350-500
Potato	500-700	Rice (paddy)	450-700
Soybean	450-700	Sugarcane	1500-2500
Tomato	400-800	Banana	1200-2200

- **Nutrition requirements :** All crops need different minerals in different quantities for their proper growth. However, all these nutrients have been classified into two types called micronutrients and macronutrients as given below in the table other than carbon, hydrogen and oxygen which plants obtain from air and water.
- **Macro-nutrients :** Nitrogen, phosphorus , potassium, sulphur, calcium , magnesium and nickel.
- **Micro-nutrients :** Zinc, copper, iron, manganese ,boron, chlorine, molybdenum and cobalt. All 14 elements must be present in the soil for plant use, in varying degrees of availability, to ensure both the immediate and long-term needs of the crop. However, depending upon the availability of a nutrient and its requirement by a plant, a nutrient can be :
- **Deficient :** When an essential element is at a low concentration that severely limits yield and produces more or less distinct deficiency symptoms. Extreme deficiencies may lead to death of the plant.
- **Insufficient :** When the level of an essential plant nutrient is below that required for optimum yields or when there is an imbalance with another nutrient. Symptoms of this condition are seldom evident.
- **Sufficient :** When the concentration of an essential nutrient is present in adequate amounts for optimum crop growth.
- **Excessive:** When the concentration of an essential plant nutrient is sufficiently high to result in a corresponding shortage of another nutrient.
- **Toxic :** When the concentration of either essential or other elements is sufficiently high to reduce plant growth severely. Severe toxicity will result in death of plants.
- **Texture and soil types :** Soils can be classified as one of four major textural classes: (1) sands; (2) silts; (3) loams; and (4) clays. Soils can be improved with help of tillage, soil cover and reforestation, soil amendment, mulching or adding compost.
- **Soil properties influenced by texture :** Drainage, water holding capacity, aeration, susceptibility to erosion, content of organic matter, cation exchange capacity and pH buffering capacity .
- **Soil types and crops :** There are different types of soils suitable for different types of crops. Some these soil types are :

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Soil type	Location in India	Crops
Alluvial soils	Northern India in delta region	Rice, wheat, sugarcane, cotton and jute all grow well in these soils
Black soils	Maharastra and Gujarat	Rice, wheat, sugarcane and cotton. It is additionally used to grow groundnut, millet and oilseeds.
Desert soils	Rajasthan and adjoining areas	Drought-resistant crops such as barley and millet
Laterite soils	Coastal areas with heavy rainfall	Cashew, rubber, coconut, tea and coffee
Mountain soils	Himalayan region	Tea, coffee, spices and many types of tropical fruits
Red and yellow soils, with lot of iron and aluminum oxide present in them.	Central India	Rice, wheat, sugarcane, millet, groundnut, ragi and potato

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- **Vegetables :** There are different categories of vegetables, such as bud, bulb, flowers, leafy, root, stem, tuber, vegetable fruit and vegetable seed. Vegetables are a recommended part of a person's daily dietary intake, and the amount depends on a person's gender, age and level of physical activity. For example, a 25-year-old man who is physically active for 30 to 60 minutes per day should have at least 3.5 cups of vegetables. Examples of different types of vegetables include
- **Bud vegetables :** Artichokes and Brussels sprouts
- **Flower vegetable :** Broccoli and cauliflower
- **Bulb vegetables :** Onions and garlic
- **Tuber vegetables :** Potatoes and yams
- **Legume vegetables :** Alfalfa, beans, chickpea, green beans, lentil and pea.
- **Leafy vegetables :** Spinach , lettuce and coriander
- **Fruit v/s vegetable :** The difference between a vegetable and a fruit is that vegetables are the edible portions of a plant, such as the leaves, stem, roots, tubers, bulbs and flowers, while a fruit is the mature ovary of a plant. Many plants that are considered fruits are botanically vegetables.
- Some plants commonly known as vegetables, such as tomatoes, squash, pepper and eggplant, are botanically fruits. Fruits don't have to be sweet. Fruits provide protection for seeds in many plants and aid in the distribution of seeds. In nature, plants produce fruit only after fertilization. However, some widely cultivated plants produce fruit without fertilization through a process called parthenocarpy. Hence, they lack seeds.

List of common spices ,plant part and uses		
Name	**Plant part used as spice**	**Uses**
Ajwain / carom seeds ajvain/Ethopian cumin	Seed	Flatulence, digestive aid, nausea and vomiting and as anti-spasmodic.
Anise/ sweet cumin	Seed	Indigestion, flatulence, breath-sweetener, coughs and sore throat.
Black pepper, a berry	Berry	Digestive system tonic, rheumatism, nausea and used as laxative.
Cardamom Cayenne/ Red pepper	Seed	Digestive aid, respiratory conditions and in liver complaints.
Clove	Flower bud	Local anesthetic, nausea, vomiting, Indigestion and Tooth aches.
Coriander	Seed	Anti-microbial, loss of appetite and digestive aid.
Cumin	Seed	Diuretic, diarrhea, indigestion and muscular spasm.
Fennel	Seed	Intestinal colic, lactation stimulant, eye wash , muscular spasm
\Fenugreek		Appetizer, diabetes, fever, and dyspepsia.
Garlic	Bulb	Antioxidant, treatment of high blood pressure and to lower blood cholesterol.
Ginger	Root	Digestive aid, bowel colic, aphrodisiac and dyspepsia.
Mustard	Seed	Dyspepsia, laxative, bowel condition and epilepsy.
Nutmeg	Seed	Diarrhea, colic, appetite loss.
Pepper corn/ black pepper/ green pepper	Berries	Colds and coughs, gum infection or inflammation, Digestive aid.
Saffron	Flower	Menstrual condition relief, sedative, and anti -spasmodic.
Sesame	Seed	Blood tonic, laxative, acne treatment, and dizziness.
Tamarind	Seed	Digestive aid , healing of wounds, sore throat and ulcers.

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Turmeric	Root	Anti-inflammatory, antioxidant, helps lower cholesterol level and used in treatment of cancer and arthritis.

- **Pests, their types and control:** Pest is an organism that causes any type of damage to the crop plants. These pests include:
- **Insect :** These are important and major pests. Insects have three pairs of legs, two pairs of wings, segmented body and characteristic compound eyes and antennae. Insects are tricky and cause damage in different ways viz. sucking sap from plants, biting plant parts, boring into fruits, twigs and leaves, attacking roots, barks and blossoms etc. The damaging stages of different insect pests are larvae, adults and nymphs.
- **Mites :** These are creatures like insect but have soft body and four pairs of legs. These tiny creatures have red or pale yellow colour. They suck the sap from the plant and attack the crops in huge number.
- **Rodents :** This group of pest eat away large amount of human food and also damage the crops on large scale. They are also responsible for heavy loss to stored grains on farms, in warehouses and houses.
- **Animals :** Animals like Wild Boar, Deer, Elephants, Wild Buffalo, Jackals, Monkeys, Squirrels cause direct damage to crop plants. They eat away the plants and by and large they waste huge amount of crops.
- **Birds :** Birds attack the crop plants and eat grains. Crow, Parrots and Sparrows are major among birds that attack the crops.
- **Methods of pest control :** Pest causes lot of reduction in the yield and quality of crops. Broadly the measures of pest control are of two types, preventive and protective. Preventive measures are used before the attack of the pest and protective measures are used to control the pest after their attack. The methods of controlling pest are as follows.
- **Mechanical methods :** Picking of pests, larvae by hand and destroying them, remove the part or whole plant that is infested, use of traps or nets to capture them.
- **Physical methods :** It includes creating high temperature or low temperature conditions as both kill the pests. The pest can also be killed by exposure to X-rays and gamma ray.
- **Cultural methods :** It includes methods such as crop rotation, deep ploughing and clean cultivation. Proper use of fertilizers and water and growing pest resistant Varieties.
- **Chemical methods :** This method is used on large scale for direct control of pests. In these methods, chemicals that kill the pest are used. These chemicals are called as Pesticides/ Insecticides. The chemical method is effective and faster as compared to other methods but it is hazardous to environment. Improper use of these chemical leads to development of resistance among the pests causing heavy out break that leads to an increase in cost of cultivation and heavy loss.
- Dusts, Wettable powders, Seed dressers, Emulsions and granules are the insecticides formulations.
- **Biological methods :** Use of biological agents to control pests is called Bio-control. Ninety eight percent pests are controlled by nature. There are certain predators, parasites, birds, animals,

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micro-organisms that can be used for control of pests. Certain biological factors used to control the pests are : Tricogama, Crysopa, HNPV, LLNPV, Chilonus, Copidosoma, Bacillus thuringenesis, Agrobacterium, etc.

- **Typical Genetically Modified Food Crops :** Almost every area in the food production market is using genetic modification to produce foods that taste better, grow faster, resist disease and improve the amount of nutrients found in the food. At times, the genetic modification helps to save natural resources because the "new" food does not need as much water or energy to be processed. Some of the well known genetically modified crops include:
- **Corn :** Corn in many areas of the country has been altered to include an insect killing gene. Hence, farmers do not have to spray pesticides that can be harmful to the environment and those farm workers who spray it.
- **Soybean :** Soya is used in the production of many items that we use every day, such as cereal, chocolate, ice cream and baked goods. Because 85% of soybeans are altered, nearly everyone is consuming altered soybeans in some way. Most soybeans are used for livestock and not for humans.
- **Sugar Beets :** One of the latest crops to be genetically altered is the sugar beet that grows faster than its native crop. Production of a modified beet began in 2008, but was banned in 2010 because the USDA failed to provide an environmental impact statement. Potatoes: Genetically modified potatoes were created to be very resistant to diseases, such as *Phytophthora infestans*. Only 25% of the potatoes grow today are eaten by people. The other 75% is used in feeding livestock and in the starch industry.
- **Tomatoes :** Tomatoes have been modified only to help them last longer so they can be transported for longer periods of time.
- **Oils :** Oils are used for cooking and flavoring. Modified oils can be sold as cooking oils, but are also used for making snacks such as potato chips. Margarine is also made by using oil. Modifications include oils losing the bitter taste they once had and making the plants more resistant to herbicides.
- **Golden Rice :** Vitamin A deficiency is a serious problem for over 250 million people around the world, This rice has been genetically altered to have vitamin A supplements carotenes added to it. Experts also want to create rice with an iron supplement to combat the iron deficiencies.

PUSA, IARI , New Delhi , Crop varieties resistant to diseases and pests:

Crop	Variety	Resistant to
Wheat	Himgiri	Leaf and stripe rust, hill bunt ,
Brassica (Rapeseed mustard)	Pusa swarnim Pusa gaurav	White rust Aphids
Cauliflower	Pusa shubhra and P.snowball k-I	Black rot and Curl blight black rot.
Cowpea	Pusa komal	Bacterial blight

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Chilli	Pusa sadhabahar	Chilly mosaic virus, Tobacco mosaic virus (TMV) and Leaf curl
Flat bean	Pusa sem-2	Aphids and fruit borers
Okara(Lady finger)	Pusa Swamani and Pusa A-4	Shoot nd fruit borer.

- **Weeds :** Weeds are the plants, which grow where they are not wanted. These weeds growing in the fields:
  - compete with crops for water, soil nutrients, light and space and thus reduce crop yields.
  - harbor insects pests and micro-organism.
  - certain weeds release into the soil the inhibitors or poisonous substances that are harmful to the plants, human beings and live-stocks.
- Weeds belong to the class Angiospermae (flowering plants) which have two subclasses: Monocotyledoneae (monocots) and Dicotyledoneae (dicots). On the basis of the habitats, they are divided into terrestrial and aquatic categories, and on the basis of the duration of life they are divided into annuals, biennials and perenials.
- **Methods to control weeds :** Measures against weeds comprise the followings :
- **Mechanical methods :** Hand-pulling or hand-weeding, hoeing, tilling, mowing, burning, flooding, smothering, etc. are examples of physical methods of weed control, The high wages paid to the hired labour narrow down the profits of the cultivator.
- **Tillage** is a practical and economical method of controlling annual weeds. The plough (disc,mould board,etc.), the harrow (disc, spike and spring-toothed) and the cultivator (duck-foot, blade,etc.) are implements in use to eradicate weeds.
- **Cultural or cropping methods :** Weeds under many conditions are better competitors than crop plants for light, water, nutrients and soil space. However, farming practices are capable of changing the condition in such a way as to enable the crop plants to compete with weeds successfully . Some of these include the proper seed-rate, depth, ,time and method of sowing, applying the most effective methods of irrigation and fertilizers and adopting a proper system of rotation.
- **Chemical methods :** The controlling of weeds in the growing crops with weedicides increases their yields. The chemical method is easier, less time-consuming and less costly than weeding by hired labourers.
  Glyphoste, 2, 4-D, 2, 4, 5-D, Naphathelene acetic acid, butachlor and atrazine are commonly used weedcides.
- **Green Revolution :** It refers to a series of research, and development, and technology transfer initiatives, that took place between the 1940s and the late 1960s, to increase agricultural production worldwide, particularly in the developing world, beginning most markedly in the late 1960s. The initiatives, led by Norman Borlaug, the "Father of the Green Revolution," who received the Nobel Peace Prize in 1970, credited with saving over a billion people from starvation, involved the development of high-yielding

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varieties of cereal grains, expansion of irrigation infrastructure, modernization of management. In the case of India, the Green Revolution at first started in the late1960s under the leadership of Swaminathan and by 1970s India attained food self-sufficiency (the first 'wave' of the Green Revolution).

Homeopathic/ Ayurvedic Medicines and Herbs			
Common name	*Scientific name*	Plant part used	Uses
Babool	*Acacia nelotica*	Stem	Diarrhea, dysentery & diabetes
Gwarpatha	*Loae barbadensis*	Leaf	Stomach ache, constipation, menstrual suppression
Ganja	*Abrus precatorium*	Seed	Purgative, emetic, nervous disorders
Makhana	*Acanthaceae tal*	Wholeplant	Diuretic, jaundice, rheumatism, genital tract treatment
Arhara	*Cajanus cajan*	Root	Snake bite
Doob	*Cynodon dactylen*	Root	Diuretic, checking bleeding frompiles, dysentery
Aak	*Calotropis procera*	Root, leaf and bark	Dysentry, intermittent fever, col, cough , asthma
Bhang	*Hibiscus cannabinus*	Leaf	Purgative, constipation
Neem	*Azadirachta indica*	Leaf, stem & root	Cold, cough , fever, Cancer
Tulsi/ Holy basil	*Ocimum tenuiflorum*	Leaf	Cold, cough and fever

Improved High Yielding Varieties		
Crop	**Name of variety**	**Characteristic**
Wheat	*Pusa kiran*	Semi-dwarf variety, resistant to stripe and leaf rust.
	Nilgiri khapli	Semi-dwarf variety, resistant to stem, leaf yellow rust.
	HDCSW IB	Resistant to brown rust and karnal bunt.
	HD 3117	Resistant to brown and yellow rust.
	Pusa malvi	Resistant to leaf and stem rust disease.
Millet	*Pusa composite*	Resistant to down mildew and blast.

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Crop	Name of variety	Characteristic
Mustard	*Zero mustard 31*	High oil content.
Cauliflower	*Pusa Betakesari*	Rich in β carotene
Melon	*Pusa sarda*	Early harvest and sweeter
Musk melon	*Pusa Madhurima*	Early harvest and sweeter
Cucumber	*Pusa seedless Cucumber-6*	Parthenocarpic with increased length and weight
Marigold	*Pusa Bahar*	Flowers are compact, flattened, attractive and large in size (8-9 cm) of yellow colour, floriferous producing on an average 50-60 flowers per plant
Rice	Lunisree & Sonamani Padmini & *Pooja Padma*, Ratna, Kalinga, Indira,Pallavi SEnha, Anjali, Tara, Hira, Vandhana	Coastal areas of India Shallow rained low land ecosystem, Well irrigated ecosystem Upland ecosystem
Maize	*Vivek - 9, Kohinoor and Aravalli* *Shaktiman-1 and Shaktiman - 2*	Higher protein content
Ground nut	*MH2, Kaushal*	Higher oil and protein content
Mustard	*Pusa Bold, Pusa agami*	Higher protein content
Soya bean	*Pusa-24, Durga*	Higher protein content
Sugar cane	Karan, Co 89003, Co 98014, Co 0118, Co 0238 and Co 0239. Co 89003,	High yielding, high sugared, early varieties

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ANIMAL HUSBANDRY

- **Animal husbandry :** It refers to the management and care of farm animals by humans, in which genetic qualities and behavior, considered to be advantageous to humans, are further developed. The term also refer to the practice of selectively breeding and raising livestock to promote desirable traits in animals for utility, sport, pleasure, or research.
- **Dairy farming :** It is a class of agriculture for long-term production of milk, which is processed (either on the farm or at a dairy plant, either of which may be called a dairy) for eventual sale of a dairy product. Dairy cows, buffaloes,, goats, sheep, and camels. In Italy, donkey dairies are growing in popularity to produce an alternative milk source for human infants.
- Animals reared in dairy farming are classified as milch breed(only for milk), draught breed(Physical work) and dual breed(Both milk and physical work).

Animal	Breed
Buffalo	Murrah, Bhadawari, Jaffarabadi, Surti, Mehsana, Nagpuri, Nili Ravi,
Cow	Kankrej, Hariana, Deoni, Jersey,Holstein Friesian , Brown swiss, Jersey cross, Guernsey, Khillari, Sahiwal, Red Sindhi, Gir
Goat	Nigerian Dwarf, Anglo-Nubian, Alpine, Sirohi, Jamunapari, Barbari, Boer, Sruti, Beetal,Sojat, Saanen
Camel	Arvana dromedaries, Somali, Bactarian,Afar, Alaxa, Kalmyk.

- **Poultry :** It refers to domesticated birds kept by humans for the eggs they produce, their meat, their feathers, or sometimes as pets. These birds are most typically members of the super order Galloanserae (fowl), especially the order Galliformes (which includes chickens, quails and turkeys) and the family Anatidae,
- **Types of poultry birds :** These are of two types called as layers and broilers. Layers are reared for eggs while broilers are reared for flesh. They differ in their diet too as the layers need diet rich in calcium as compared to broilers whose diet need to be rich in protein content.
- **Broiler :** They are young chicken of either sex, are reared primarily for meat purposes and marketed at an age of 6-8 weeks.
- **Grower :** The management of birds during 9-20 weeks or to the point of laying is referred to as grower period.
- **Layer :** The management of birds during 21-72 weeks of age for the purpose of laying eggs (egg production).

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- **Advantages of Chicken farming :** It has number of advantages which include
  - initial investment is a little lower than layer farming.
  - small rearing period is 6-7 weeks only.
  - more number of flocks can be reared in the same shed.
  - broilers have high feed conversion efficiency i.e. least amount of feed is required for unit body weight gain in comparison to other livestock.
  - faster return from the investment.
  - demand for poultry meat is more compared to sheep/goat meat.

Classification of Breeds of Poultry :

American class : New Hampshire, White Plymouth, RhodeIsland red and WyandoteII

Mediterranean class : Leghorn, Minorca, Ancona

English class : Australop, Sussex, Orphington

Indian class : Asil and Kadaknath.

Poultry and fowls reared

Bird	Utilization
Chicken	meat, feathers, eggs, ornamentation, leather
Duck	meat, feathers, eggs
Emu	meat, leather, oil
Goose	meat, feathers, eggs
Indian pea fowl	meat, feathers, ornamentation, landscaping
Mute swan	feathers, eggs, landscaping
Ostrich	meat, eggs, feathers, leather
Pigeon	meat, feathers, ornamentation, sports
Turkey	meat, feathers
Guinea fowl	meat, pest consumption, and alarm calling
Common pheasant	meat
Greater rhea	meat, leather, oil, eggs

Native breeds of egg type chicken in India

Breed	Body weight (20 weeks)	Age at sexual maturity (days)	Annual egg production (No.)	Hatchability FES (5)
Aseel	1220	196	92	63
Frizzle	1005	185	110	71
Kadaknath	920	180	105	52
Naked neck	1005	201	99	71

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Commercial Broiler strains :

Eg. Cobb, Hubbard, Lohman, Anak 2000, Avian -34, Starbra, , Vama, Caribaro, etc.,

Commercial Layer Strains :

Eg.Aseel, Frrizle, Rhode Islandred, Plymouth, Kadarnath, etc.

- **Apiculture:** Apiculture or beekeeping is the practice of maintaining honeybee colonies, usually in hives.
  This could be for collecting honey and bees wax, or for pollinating crops, or for the purpose of selling bees to other beekeepers.

Advantages of Beekeeping:

1. Beekeeping requires less time, money and infrastructure investments.
2. Honey and bee wax can be produced from an area of low agriculture value.
3. Bee keeping has positive ecological value as bees are very good pollinators.
4. Honey collected is very nutritious particularly in sugar(38%-55% Fructose, 31% glucose and other sugars), minerals and vitamins.
5. Honey, bee wax and bee venom all have good market value.

- **Composition of honey :** 80% carbohydrates, 18% water and 2% amino acids, vitamins, and minerals. It's pH range is from 3.4 to 6,
  - 18 types of amino acids
  - Guconic acid is made by the glucose oxidase enzyme
  - Enzymes like diastase (amylase), and invertase (glucosidase)
  - Vitamin B6, niacin, thiamine, pantothenic acid, and riboflavin.
- **High yielding species of honey bees :** *Apis indica, A. dorsata and A. malifera* (Highest yieilding but Italian breed).
- **Pisciculture :** It also called fish farming involves raising fish commercially in tanks or enclosures, usually for food. It is the principal form of aquaculture, while other methods may fall under mariculture. A facility that releases juvenile fish into the wild for recreational fishing or to supplement a species' natural numbers is generally referred to as a fish hatchery., The most important fish species used in fish farming are carp, tilapia, salmon and catfish reared by composite culture method. It involves rearing of shallow water feeder , mid water feeder and deep water feeders together in same pond /tank. Fish used in composite culture system include catla and silver carp which are surface feeders, rohu a column feeder and mrigal and common carp are bottom feeders.
- **Fry :** Newly hatched fish
- **Fingerling :** Young fish or baby fish
- **Hatchery :** A unit where fish eggs are hatched artificially into fry.
- **Aquaculture v/s pisciculture :** Aquaculture is the farming of freshwater and saltwater organisms such as finfish, mollusks, crustaceans and aquatic plants. Aquaculture also called Aqua forming involves cultivating aquatic populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish. Commercial aquaculture supplies one half of the fish and shellfish that is directly consumed by humans.

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- **Pisciculture :** or Fish farming is the principal form of aquaculture, while other methods may fall under mariculture. Fish farming involves raising fish commercially in tanks or enclosures, usually for food.
- **Sericulture :** It is the rearing of silkworms for the production of silk. Although there are several commercial species of silkworms, *Bombyx mori* (the caterpillar of the domesticated silk moth) is the most widely used breed.
- The silk is a continuous filament comprising fibroin protein, secreted from two salivary glands in the head of each larva, and a gum called sericin, which cements the filaments. The sericin is removed by placing the cocoons in hot water, which frees the silk filaments and readies them for reeling. This is known as the degumming process. The immersion in hot water also kills the silkworm pupae. Therefore, the environmentalists oppose sericulture.
- **Importance of sericulture :** Sericulture provides gainful employment, economic development and improvement in the quality of life to the people in rural area and therefore it plays an important role in anti poverty programme and prevents migration of rural people to urban area in search of employment.

Types of silk worms and silk :

- **Mulberry :** The bulk of the commercial silk produced in the world comes from this variety and often silk generally refers to mulberry silk. Mulberry silk comes from the silkworm, Bombyx moriL. which solely feeds on the leaves of mulberry plant.
- **Tasar :** Tasar (Tussah) is copperish colour, coarse silk mainly used for furnishings and interiors. It is less lustrous than mulberry silk, but has its own feel and appeal. Tasar silk is generated by the silkworm, *Antheraea mylitta* which mainly thrive on the food plants Asan and Arjun. Tasar culture is the main stay for many a tribal community in India.
- **Oak Tasar :** It is a finer variety of tasar generated by the silkworm, Antheraea proyeli J. in India which feed on natural food plants of oak, found in abundance in the sub-Himalayan belt of India covering the states of Manipur, Himachal Pradesh, Uttar Pradesh, Assam, Meghalaya and Jammu & Kashmir. China is the major producer of oak tasar in the world .
- **Eri :** It also known as Endi or Errandi, Eri is a multivoltine silk spun from open-ended cocoons, unlike other varieties of silk. Eri silk is the product of the domesticated silkworm, *Philosamia ricini* that feeds mainly on castor leaves.. It is also found in Bihar, West Bengal and Orissa.
- **Muga:** It is golden yellow colour silk is prerogative of India and the pride of Assam state. It is obtained from semi-domesticated multivoltine silkworm, *Antheraea assamensis*. These silkworms feed on the aromatic leaves of Som and Soalu plants and are reared on trees similar to that of tasar. Muga culture is specific to the state of Assam.

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UNIT-IV

SCIENCE & TECHNOLOGY

1. SPACE RESEARCH IN INDIA
2. 1969 AND INDIA'S SPACE PROGRAMME
3. ISRO AND MAJOR ACHIEVEMENTS
4. TYPES OF SATELLITES AND THEIR APPLICATIONS
5. SCIENCE AND TECHNOLOGY IN DEFENCE SECTOR
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Chapter 1

SCIENCE & TECHNOLOGY

Space research in India : It began in the 1920s with studies conducted by scientists S K Mitra, C V Raman and Meghnad Saha. However, it was only from 1950s that institutionalized probe into space related activities gained momentum and nationwide attention. However, at this time, space studies were restricted to aspects of Earth's atmosphere, weather prediction and the surrounding magnetic field.

Dawn of Space Research in India : It was in 1962 India reached its first milestone when Pandit Jawaharlal Nehru along with scientist Vikram Sarabhai established the Indian National Committee for Space Research (INCOSPAR). Following the establishment of the INCOSPAR, the first rocket launch from India took place in November 1963.

1969 and India's Space Programme: With time the ICONOSPAR grew fast to become the Indian Space Research Organisation (ISRO) in 1969. With the establishment of the ISRO and further with the government of India forming the Space Commission for policy formulation and the Department of space, research and execution of space related enterprises got an unexpected boost in its research programmes.

ISRO and major achievements : ISRO once established in 1969 has a list of achievements that seems limitless. Among all the achievements that underlie the fruits of untiring efforts ISRO and its sister organizations spread across the country, some are as follows:

- 1975 : The first Indian satellite, Aryabhata, was launched using a Russian rocket. It provided India with the basis of learning and designing its own satellite technology.
- 1976-77 : Satellite Telecommunication Experiments Project (STEP) was launched as a sequel of SITE. It used satellite technology for enhancing domestic communication.

  SLV-3 placed the Rohini satellite, RS-1, in orbit, thereby making India the sixth member of an exclusive club of space-faring nations.
- 1980 : The first indigenously created satellite vehicle was launched from Sriharikota, Andhra Pradesh. SLV-3 placed the Rohini satellite, RS-1, in orbit making India the sixth member of an exclusive club of space-faring nations.
- 1984 : The first Indo-Soviet manned space mission was launched. Rakesh Sharma became the first Indian citizen to go into space. He flew aboard in the Soviet rocket Soyuz T-11, as part of a three member Soviet-Indian crew.
- 2008 : In October 2008, the first lunar mission launched by ISRO. The spacecraft, Chandrayaan took off from the Satish Dhawan Space Centre and it operated till August 2009. The project was announced by former PM Atal Bihari Vajpayee, as part of his independence day speech in 2003. ISRO plans to launch its second lunar mission, Chandrayaan 2 by 2018.

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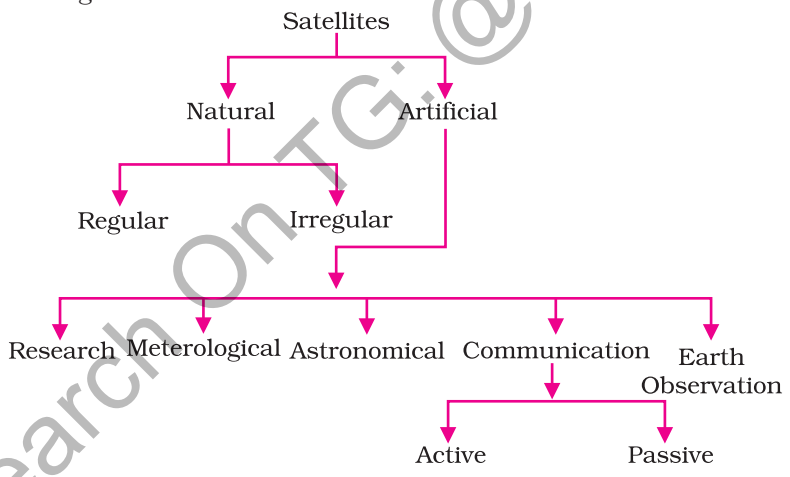
- 2014: Mangalyaan, India's first interplanetary mission was launched, making ISRO the fourth space agency to reach Mars. Mangalyaan gained worldwide repute as being the least expensive Mars mission till date

Satellites and India: India has launched 104 satellites (3 are Indian, 96 are from USA and one each from Switzerland, Netherlands, UAE, Israel and Kazakhstan) on 15 February 2017 of many types since its first in 1975. Satellites have been launched from various vehicles, including those launched by American, Russian and European rockets, as well as those launched indigenously by India. The organisation responsible for India's satellite program is the Indian Space Research Organisation (ISRO).

- India becomes the first country to script history after launching the 104 satellites in a single rocket on 15 February 2017.

TYPES OF SATELLITES AND THEIR APPLICATIONS

A satellite is an object that orbits about somebody (i.e. planet, dwarf planet, asteroid, or star of a larger size.) capable of exerting a gravitational force. Generally, the satellites have been classified in following classes:



Natural Satellites : A natural satellite is a celestial body that orbits a planet or other body larger than itself. The term is normally used to identify non-artificial satellites of planets, dwarf planets, or minor planets. Such objects are often called moons.There are upto 240 known moons within the solar system, including 163 orbiting the planets, four orbiting dwarf planets.

Earth's Moon is the most obvious example and was the only one known until the discovery of the Jupiter in 1610. All the solar system's planets except Mercury and Venus have moons. They vary greatly in size, composition (from rock to mostly icy), and activity (from cold and inert to volcanic).

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Natural Satellites : They are of two types

Regular satellite : It is a natural satellite following a relatively close and generally prograde orbit with little orbital inclination or eccentricity. They are believed to have been formed in orbit about their primary, as opposed to irregular moons, which were captured. The regular satellites are two of Mars, inner five of Jupiter, inner seven of Saturn etc.

Irregular satellite : It is a natural satellite following a distant, inclined, and often eccentric and retrograde orbit. They are believed to have been captured by their parent planet, unlike regular satellites, which were formed in situ.

Artificial Satellites : These are man-made devices placed in orbit around the earth, moon, or another planet used for communication and transmitting scientific information to earth.

The electrical power required by satellite is provided by panels of solar cells and small nuclear reactors. These satellites are kept in the correct position by small rocket motors called thrusters. They orbit with their disc aerials pointing to Earth. When the thrusters run out of fuel, the satellite eventually drifts out of position and becomes unusable. Satellites are equipped with radio transmitters, radio receivers and electronic circuits for storing data.

First artificial satellite : It was Sputnik I, was launched by the USSR on October 4, 1957 into orbit around Earth. Since then, thousands have been sent into orbit around Earth as well as the Moon, Venus, Mars, Jupiter, and other bodies

Uses of artificial satellites : The list include their use in

- Long distance communications such as in television, fax, internet etc
- Television and radio broadcasting etc
- Weather forecasting i.e. in prediction of rainfall, snowfall, storm etc
- Agricultural monitoring i.e. crop disease, crop failure.
- Collecting information about other planets, stars and other celestial bodies

Types of artificial Satellites : All the known artificial satellites based on their functions have been classified into six principal types.

Research satellites : These measure fundamental properties of outer space, e.g. magnetic fields, the flux of cosmic rays and micrometeorites, and properties of celestial objects that are difficult or impossible to observe from the earth. Notable research satellites have included the Hubble Space Telescope , the Compton Gamma-Ray Observatory, the Infra-red Space Observatory, and the Solar and Heliospheric Observatory.

Communications satellites : These provide a worldwide linkup of radio, telephone and television. The first communication satellite was Echo 1, launched in 1960. Relay 1 and Telstar 1, both launched in 1962, were the first active communications satellites; Telstar 1 relayed the first live television broadcast across the Atlantic Ocean.

There are two types of these satellites :

Passive satellites : These satellites receive the electromagnetic signal from the source or transmitter and redirect it towards the receiver or desired destination.

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The electromagnetic signal transmitted from the source collides continuously with the atmospheric particles. Because of this continuous collision, the signal strength is reduced. Hence, the receiver receives a weak signal.

Active satellites : These satellites receive the signal from the source, amplify the signal, and redirect the signal toward the receiver. However, the active satellite amplifies the signal to a desired level and redirects the signal towards the receiver.

Weather satellites (meteorological) satellites : These provide continuous, up-to-date information about large-scale atmospheric conditions such as cloud cover and temperature profiles. Tiros 1, the first such satellite was launched in 1960; it transmitted infrared television pictures of the earth's cloud cover and was able to detect the development of hurricanes and to chart their paths. Current weather satellites can transmit visible or infrared photos, focus on a narrow or wide area, and maneuver in space to obtain maximum coverage.

Earth Observation Satellites : These include the largest civilian remote sensing satellite constellation in the world - thematic series of satellites supporting multitude of applications in the areas of land and water resources; cartography; and ocean & atmosphere. These satellites detect the changes in the earth vegetation, ocean color, radiations from the earth surface. These satellites are also used to map the terrain. The various earth observation satellites are like Environmental Satellite (Envisat).

Astronomical satellites : These satellites are used to observe the distant galaxies, stars, planets, natural satellites, and other objects in the space. Astronomical satellites are mainly used to find the new planets, stars, and galaxies.

Hubble space telescope : It is one of the most famous and largest astronomical satellites. It captures extremely high-resolution images from the space.

Navigation satellites : These were developed primarily to satisfy the need for a navigation system that nuclear submarines could use to update their inertial navigation system.

Military Satellites : These satellites are used for a number of military purposes, including infrared sensors that track missile launches; electronic sensors that eavesdrop on classified conversations; and optical and other sensors that aid military surveillance.

Satellite Types And Orbit : Satellites are usually classified according to the type of orbit they are in. There are four types of orbit associated with satellites, and it's the type of orbit that dictates a satellite's use.

Low Earth Orbits : Satellites in low Earth orbits are normally military reconnaissance satellites. They can pick out tanks from 160 km above the Earth. They orbit the earth very quickly with one complete orbit normally taking 90 minutes.

Sun-Synchronous orbits : Meteorological satellites are often placed in a sun-synchronous or helio-synchronous orbit. These satellites are in polar orbits. These meteorological satellites orbit the Earth 15 to 16 times per day.

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Geosynchronous satellites : These satellites also called Earth-synchronous satellites are placed into orbit such that their period of rotation exactly matches the period of Earth's rotation i.e. 24 hours to make one rotation. However, the plane of orbit for these satellites is generally not the equatorial plane. Apart from geostationary satellites, these satellites are used for communications at high latitudes, particularly in Russia and Canada. The orbits are called Molniya orbits. In twenty four hours, they move over the Earth in a figure of eight pattern centered on a fixed longitude, moving slowly where they can be useful and quickly where they are of little or no use.

Geostationary satellites : The majority of communications satellites are geostationary satellites.. These satellites take 24 hours to complete a rotation as positioned directly over the equator and their path follows the equatorial plane of the Earth. Hence, they don't move North or South during the day and are permanently fixed above one point on the equator of the Earth.

Most video or T.V. communications systems use geostationary satellites. Geosynchronous and geostationary satellites typically orbit at 35,788 km (22,238 miles) above the surface of the planet (42,000 km from its centre).

Launchers in Space Progrqmme : Launchers or Launching Vehicles are used to carry spacecraft to space. India has two operational launchers: PSLV and GSLV while the use of 3rd is in its initial phase.

Polar Satellite Launch Vehicle (PSLV) : Polar Satellite Launch Vehicle was developed to launch Low Earth Orbit satellites into Polar and Sun Synchronous Orbits. It has proved its versatility by launching Geosynchronous, Lunar and Interplanetary spacecraft successfully.

Geosynchronous Satellite Launch Vehicle (GSLV) : It was developed to launch the heavier INSAT class of Geosynchronous satellites into orbit. In its third and final stage, GSLV had used the indigenously developed Cryogenic Upper Stage.

GSLV Mk - III : It is a third launcher of higher payload capacity. It is being developed and will be launched on its first experimental flight later this year. In order to achieve high accuracy in placing satellites into their orbits, a combination of accuracy, efficiency, power and immaculate planning are required.

Launching facilities in India:

- Vikram Sarabhai Space Centre, located in Thiruvananthapuram, is responsible for the design and development of launch vehicles.
- Liquid Propulsion Systems Centre and ISRO Propulsion Complex, located at Valiamala and Mahendragiri respectively, develop the liquid and cryogenic stages for these launch vehicles.
- Satish Dhawan Space Centre, SHAR, is the space port of India and is responsible for integration of launchers. It houses two operational launch pads from where all GSLV and PSLV flights take place while presently a third launch pad is also under development.

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List of Some Major Indian Satellites launches since 2014.

Satellite	Launch	Launch Vehicle	Resource
IRNSS-1D	2015	PSLV-C27	IRNSS-1D is the fourth satellite in the Indian Regional Navigation Satellite System (IRNSS).
GSAT-6	2015	GSLV-D6	GSAT-6 is a communication satel lite. GSAT- 6 features an unfur lable antenna, largest on board any satellite. Launch of GSLV-D6 also marks the success of indig-enously developed upper stage cryogenic engine
Astrosat	2015	PSLV-C30	ASTROSAT is India's first dedicat-ed multi wavelength space Observatory.
GSAT-15	2015	Ariane-5 VA-227	Communications satellite, carries communication transponders in Ku-band and a GPS Aided GEO Augmented Navigation (GAGAN) payload operating in L1 and L5 bands. Weight 3164 kg.
IRNSS-1E	2016	Series of SLV-C31, C32, C33	Series of IRNSS-1E, IRNSS- IF and IRNSS-IG is the fifth satellite in the (Indian Regional Navigation Satellite System)
Cartosat -2D	2017	PSLV-C37	Highest number of satellites launched by a single launch vehicle (104 satellites)
SAARC Satellite	2017	GSLV—F09	Satellite for regional cooperation and connectivity among South-Asian countries except Pakistan.
Commu-nication satellites to Geosyn-chronus Transfer Orbit	2017	GSLV Mk III	The first experimental flight of heavy lift next generation launch vehicle, GSLV-Mk III. It is designed to launch 3.5 to 4 Ton class communication satel-lites to Geosynchronous Transfer Orbit.

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Indian Regional Navigational Satellite System(IRNSS)

It is both for commercial and military purposes operated by ISRO. It is active within the range of 1500km from borders with seven satellites.

The project NAVIC (Navigation with Indian Constellation) was approved by Indian government in May 2006.

GNSS and GPS as satellite navigation system

A satellite navigation system is a system of satellites that provides autonomous geo-spatial positioning with global coverage. It also allows small electronic receivers to determine location (longitude, latitude, and altitude/elevation) using time signals transmitted along a line of sight by radio from satellites. Often times the terms "GNSS" and "GPS" are used interchangeably but there are key differences between the two .

GNSS (Global Navigation Satellite System) : It is the standard generic term used globally for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage The advantage of having access to multiple satellites is accuracy, redundancy and availability at all times. Common GNSS Systems are GPS and GLONASS.

GPS (Global Positioning System) : It consists of up to 32 medium Earth orbit satellites in six different orbital planes, with the exact number of satellites varying as older satellites are retired and replaced by new ones. GPS is currently the world's most utilized satellite navigation system

Satellite Communications : Presently, it is difficult to go through a day without using a communications satellite at least once because anytime when you watch T.V., make a long distance phone call, use a cellular phone, a fax machine, a pager, or even listen to the radio; you probably use a communication satellite, either directly or indirectly.

Characteristic features of communication satellites:

- These satellites allow radio, television, and telephone transmissions to be sent live anywhere in the world.
- Some of these satellites have a passive role in communications i.e. merely bouncing signals received back to earth. These satellites carry electronic devices called transponders for receiving, amplifying, and re-broadcasting signals to the Earth.
- Most of these satellites are positioned in geostationary orbit.
- Communications satellites can also be in highly elliptical orbits. It is roughly egg-shaped, with the Earth near the top of the egg. In a highly elliptical orbit, the satellite's velocity changes depending on it's position in orbital path. When the satellite is in the part of its orbit close to the Earth, it moves faster because the Earth's gravitational pull is stronger.
- The data carried by communication satellites is used for a wide variety of applications. Television, telephones, computer networks and fax are more regularly sent to and from satellites They relay information and data transmitted from one area of Earth to an-

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other. Signals are transmitted via radio dish to the satellite from one region of the planet, which then broadcasts the signal back again to a receiver in another part of the world.

Advantages of satellites communication : Satellite communications has unique advantage over conventional long distance transmissions as the satellite links are not affected by the propagation variations that interfere radio communication. They are also free from the high attenuation of wire or cable facilities and are capable of spanning long distances. The numerous repeater stations required for line-of-sight or troposcatter links are no longer needed. They furnish the reliability and flexibility of service necessary to support a military operation.

Mobile Satellite Communications : Satellite communications systems use a directional antenna (usually a "dish") pointed at a satellite. The antenna on a moving ship or train, for example, must be pointed based on its current location. Modern antenna controllers usually incorporate a GNSS receiver to provide the above information. In Emergency location based GNSS functionality can be used by emergency services to locate cell phones

Telescopes and types: Telescopes are optical devices used to view the distant objects.

Telescope type	Features and apllications
Gamma ray	It collect and measure individual, high energy gamma rays from astrophysical sources. These are absorbed by the atmosphere, requiring that observations are done by high-altitude balloons or space missions. Gamma rays are generated by supernovae, neutron stars, pulsars and black holes.
X-ray telescopes	These telescope measure high-energy photons called X-rays. These cannot travel a long distance through the atmosphere hence, can only be observed high in the atmosphere or in space. Some Solar System bodies emit X-rays, the most notable being the Moon, although most of the X-ray brightness of the Moon arises from reflected solar X-rays.
Ultraviolet telescopes	These telescopes make observations at ultraviolet wavelengths, i.e. between 10 and 320nm. Light at these wavelengths is absorbed by the Earth's atmosphere, so observations at these wavelengths have to be performed from the upper atmosphere or from space. Objects emitting ultraviolet radiation include the Sun, other stars and galaxies.
Infra-red light telescope	Infra-red light is of lower energy than visible light, hence is emitted by cooler objects. The infrared: cool stars, nebulae, and red shifted galaxies can be viewed using them.

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Microwave space telescopes	These are primarily used to measure cosmological parameters from the Cosmic Microwave Back ground. They also measure synchrotron radiation, free-free emission and spinning dust from our Galaxy, as well as extragalactic compact sources and galaxy clusters through the Sunvaev-Zel'dovich effect.
Radio telescope	The atmosphere is transparent for radio waves, radio telescopes in space are of mostly used for very long Baseline interferometry; doing simultaneous observations of a source with both a satellite and a ground-based telescope and by correlating their signals to simulate a radio telescope the size of the separation between the two telescopes. Observations can be of supernova remnants, masers, gravitational lenses, starburst galaxies, and many other things
Gravitational waves telescope	A proposed new type of telescope is one that detects gravitational waves; ripples in space-time generated by colliding neutron stars and black holes.

SCIENCE AND TECHNOLOGY IN DEFENCE SECTOR

Defence Research and Development Organisation (DRDO) : It is an agency of the Republic of India, charged with the military's research and development, headquartered in New Delhi, India. In 1958, it was formed by the merger of the Technical Development .

- It works under the administrative control of the Ministry of Defence, Government of India.
- It has a network of 52 laboratories, engaged in developing defence technologies covering various fields such as aeronautics, armaments, electronics, land combat engineering, life sciences, materials and missiles.

DRDO and Aeronautics : DRDO is responsible for the ongoing Light Combat Aircraft (LCA) to

- develop the aviation industry in India with flight control systems, aircraft propulsion and composite structures, along with aircraft design and development
- provide the Indian Air Force with a modern, fly by wire, multi-role fighter.

DRDO and Su–30MKI programme : The DRDO provided key avionics for the Sukhoi Su-30MKI programme under the "Vetrivel" programme. Systems developed by DRDO include radar warning receivers, radar and display computers. DRDO's radar computers, manufactured by HAL (Hindustan Aeronautics Limited) are also being fitted into Malaysian Su-30s.

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DRDO and upgrading of MIG-27 : The DRDO is part of the Indian Air Force's upgrade programmes for its MiG-27 and Sepecat Jaguar combat aircraft, along with HAL., the manufacturer DRDO and HAL have been responsible for the system design and integration of subsystems like the Tarang radar warning receiver, Tempest jammer, core avionics computers, brake parachutes, cockpit instrumentation and displays.

HAL AMCA : Aeronautical Development Agency of DRDO is responsible for the design and development of the fifth generation aircraft.

Avtar : It's a spacecraft *i.e.*an Aerobic Vehicle for Trans-atmospheric Hypersonic Aerospace Transportation). It is a concept study for a unmanned single-stage reusable space plane capable of horizontal take off and landing, by India's DRDO. The mission concept is for low cost military and commercial satellite space launches.

Avatar as space plane vehicle can take off from conventional airfields. Its liquid air cycle engine collects air in the atmosphere on the way up, liquefy it, separate oxygen and store it on board for subsequent flight beyond the atmosphere. The Avatar is a reusable launch vehicle.

Other Hindustan Aeronautics programmes : Apart from the abovementioned upgrades, DRDO has also assisted HAL with its programmes such as in HAL Dhruv *helicopter and* HAL HJT-36.

Over a hundred LRU (Line Replaceable Unit)'s in the HJT-36 have come directly from the LCA programme

Name	Features and applications
Unmanned aerial vehicles (UAVs)	It is two unmanned aerial vehicles while the third one 'Rustom' is at the brink of its development.
Nishant tactical UAV	It is a hydraulically launched short-ranged UAV for the tactical battle area. It is currently being evaluated by the Indian Navy and the Indian Paramilitary forces as well
Lakshya (Target)	Pilotless Target Aircraft (PTA). Presently, the Lakshya PTA has been ordered by all three services for their gunnery target training requirements. Efforts are on to develop the PTA further, with an improved all digital flight control system, and a better turbojet engine.
Rustom	A new class of UAVs is soon expected to be developed by DRDO with the experience gained via the Nishant programme, with substantially more capability .

DRDO and future plans : Presently, it speaks of converting the LCA into a UCAV (Unmanned combat aerial vehicle), and weaponising UAVs. Some of these on the list include:

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DRDO Abhyas : It is a high-speed expendable aerial target (HEAT) being built by the Aeronautical Development Establishment (ADE) of DRDO for the Indian Armed Forces. Abhyas's radar cross-section (RCS) as well as its visual and infrared signatures can be augmented to simulate a variety of aircraft for air-defense weapon practices. It can also function as a jammer platform and decoy. The HEAT system is utilized to do away with the post-launch recovery mode, which is time-consuming and difficult in a scenario as the sea.

DRDO AURA : It is an autonomous unmanned combat air vehicle(UCAV) i.e. Unmanned Stealth Bomber being developed by DRDO for the Indian Air Force and Indian Navy. The design work on the UCAV is to be carried out by Aeronautical Development Agency (ADA). Looking into its capability of releasing missiles, bombs and precision-guided munitions when and where required.

DRDO Imperial Eagle : It is an Indian light-weight(2.5kg) mini-unmanned aerial vehicle (UAV) developed by DRDO and supported by private vendors. Its primary users are the National Security Guard and the military services. It can carry both a daylight camera and thermal night vision camera.. With a ground tracker system, it is capable of providing continuous imagery of the on-board camera irrespective of the attitude of the aircraft.

DRDO Pawan : It is an unmanned aerial vehicle (UAV) developed by India's ADE (Aeronautical Development Establishment), a branch of DRDO for the Indian Armed Forces and the Israel Aircraft Industries. It has both day-and-night surveillance capability, an endurance of five hours and a range of 150 kilometers.

Rustom Unmanned aerial vehicle (UAV) : The UAV is combat aerial vehicle that can be equipped with electro optic sensors, radar, electronic intelligence, communication intelligence and situational awareness payloads. The Rustom-II is a Medium Altitude Long Endurance (MALE) UAV.

DRDO Uika : It has also been developed by ADE. It has been designed to be launched from subsonic or supersonic aircraft by means of an ejector release unit. It performs missions between 50 m to 13,000 m altitude at speeds ranging from 0.7 to 1.4 Mach with a rocket motor. It is able to simulate the speed and altitude characteristics of approaching, receding or crossing of a variety of aircraft using false radar signatures. It is used for defensive training of surface-to-air missile crews against anti-ship missiles and for development testing and evaluation of air defense systems. It can be air-launched by a variety of aircraft.

DRDO Artillery systems and ammunition	
Name	**Features and applications**
Pinaka multi barrel rocket launcher	Till date,the Pinaka Mk1 system, with rockets of up to 40 km striking distance, has been successfully inducted in the Indian Army.

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Prahaar	It is a long-range tactical rocket system meant to strike at a range of 100–120 km, with each rocket in the system, having a payload of up to 250 kg. The rocket has a maximum speed of 4.7 mach and rises to an altitude of 40 km, before hitting its target at 1.8 mach.
Illuminating bomb	It developed by DRDO 81 mm and the 120 mm illuminating bombs and 105 mm illuminating shells for the Indian Army's infantry and Artillery.
Lightweight Infantry	It is 51mm long mortar developed for the Indian army.
Platoon Mortar	A man portable weapon, achieves double the range of 2-inch (51 mm) mortar without any increase in weight. Its new HE bomb uses pre fragmentation technology to achieve improved lethality. The weapon system is under production at Ordinance Factories.

Training devices : These devices include a mortar training device for the 81 mm mortar used by the infantry, a mortar training device for the 120 mm mortar used by the artillery, and a 0.50-inch (13 mm) sub-calibre training device for 105 mm Vijayanta tank gun.

Indian Field Gun : It is a 105 mm field gun developed for the Indian Army. This was a significant challenge for the OFB, and various issues were faced with its manufacture including reliability issues and metallurgical problems but these had been rectified over time.

INSAS Assault Rifle : The INSAS weapon system has become the standard battle rifle for the Indian Army and paramilitary units. It has also been selected as the standard assault rifle of the Royal Army of Oman.

DRDO Achievements In 2016

- Portable Telemedicine System for Armed Forces: The Portable Telemedicine System (PDF) for Armed Forces was developed by the Defence Bioengineering and Electromedical Laboratory (DEBEL), Bengaluru in 2016. It is meant to provide remote assistance to injured personnel in a field hospital or a ship out at sea. The telemedicine system has successfully been demonstrated on board the ships INS Deepak, Gomati, and Talwar.
- **Devastating new Tank Ammunition :** Armament Research and Development Establishment (ARDE) and the High Energy Materials Research Laboratory (HEMRL), research wings of the DRDO in Pune designed new ammunition meant specifically for the Arjun tank. The Penetration-cum-Blast (PCB) and Thermobaric (TB) Ammunition were successfully test fired in Odisha, demonstrating the

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devastating power of the ammunition against concrete structures, fortifications and armour plates.

Indian Navy and biodiesel : The Indian Navy has created a Energy and Environment Cell tasked with making the Indian Navy an environmentally responsible force. The Indian Navy using the opportunity of World Environment Day to outline some of the initiatives taken to reduce the carbon footprint showcased Fast Interception Craft (FIC) in the Presidential column that were running on biodiesel produced by the Defence Institute of Bio-Energy Research (DIBER). The FIC running on biodiesel are marked with two green stripes, and are known as the Green Strike Force.

Indigenous Sonar Dome : The Sonar dome is attached to the bottom of ships. It scans the seas for submarine threats. The research and development needed for manufacturing the dome was conducted by a Pune based DRDO lab known as Research and Development Establishment (Engrs) (RDE(E)). The dome was manufactured by Kineco Ltd, a composites manufacturing company based in Pilerne, Goa.

Varunastra torpedo : Torpedo are the naval systems to provide underwater defence. Varunastra is a ship launched heavy weight torpedo, also known as an underwater missile

The upcoming of the torpedo came as an important milestone in pushing India towards self reliance w.r.t. underwater defense capabilities. The Rajput and Delhi class of warships can be equipped with the new torpedos, and future Anti-Submarine Warfare capable ships.

HAL Tejas : The Indian Air Force inducted two Tejas aircrafts into its 45th squadron in July. The Light Combat Aircraft were jointly developed by Hindustan Aeronautics Limited (HAL) and Aeronautical Development Agency (ADA). The aircraft can take up a variety of roles in combat, and are supersonic.

The Tejas is capable of carrying four tonnes of weapons. The aircraft are capable of firing air-to-air missiles, and dropping laser guided bombs. The aircraft includes a head mounted display for the pilot, and a glass cockpit on which real time information is displayed.

Indian Army and Missiles	
Missile	Important features and applications
MRSAM (Medium Range Surface-to-Air Missile)	In efforts of boosting India's indigenous defence capabilities ,these missiles have a range of 70 kilometres. They are meant to handle any kind of aerial threats including fighter aircraft and helicopters.
LRSAM (Long Range Surface-to-Air Missile)	LRSAM developed jointly by DRDO and Israel Aerospace Industries, similar to the MRSAM. These tests using LRSAM have boosted India's defence capabilities in technologically challenging areas.

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Nag, an anti-tank missile	It joined the ranks of indigenously developed missiles by the Integrated Guided Missile Development Programme (IGMDP). It is meant to tackle modern battle tanks and other heavily armoured tanks. It's a program that was lead by former president Abdul Kalam. The Nag joins Agni, Prithvi, Trishul and Akash. The Nag is a lock on-before-launch (LOBL), fire-and-forget, anti-tank guided missile.

Indian Army and Main Battle Tanks

Tank type	Important features and applications
Arjun Tank	It has a 120 mm main rifled gun, one PKT 7.62 mm well coaxial machine gun, and a NSVT 12.7 mm machine gun. Powered by a single MTU multi-fuel diesel engine rated at 1,400 hp Speed : 67 km/h (42 mph) Crew: Four-men crew: commander, gunner, loader and driver
T-90 Bhishma Tank	It supports a new automatic loader, Fire Control System (FCS), main gun (2A46M-5) and power plant of 1,130 horsepower output. Atop at its turret is seated an optional remote-controlled Anti-Aircraft (AA) gun. Production of the tanks is handled locally by Heavy Vehicles Factory of Avadi.
T-72 Ajeya Tank	It developed by DRDO is Combat Improved Ajeya (CIA) and later Upgraded to advanced Ajeya Mk1 and MK2 standard. These tanks have thermal Image Fire Control System (TIFCS), Muzzle Reference System (MRS), Explosive Variants of radar, Integrated fire Army, Navy and Air Force. Detection & Suppression System (IFDSS), and Global Positioning System (GPS).
T-55 MBT and Vijayanta Tank	Both these tanks once considered 'Bharat Rakshak' are now withdrawn from service of Indian Army since 2008. These are now in storage or display.

LIST OF INDIAN MISSILES

Missile Name	Orgin	Type	Range	Speed
AIR-TO-AIR MISSILES				
Astra	India	Air-to-Air Missiles	60 – 80 km	Mach 4 +
K-100	Russia & India	Medium Range Air-to-Air Missile	300–400 km	Mach 3.3
MICA	IAF	Air-to-Air Missiles		

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Surface-To-Air Missiles				
Akash	India	Medium-range surface-to-air missile	30-35km	Mach 2.5 to 3.5
Barak 8	Isreal /India	Long Range surface to air Missile	100 km	Mach 2
Trishul	India	Short Range surface to air missile	9km	
Defence Missile				
Prithvi Air Defence (PAD)	India	Exo-atmospheric Anti-ballistic missile	Altitude-80km	Mach 5+
Advanced Air Defence (AAD)	India	Endoatmospheric Anti-ballistic missile	Altitude-30km	Mach 4.5
Prithvi Defence Vehicle (PDV)	India	Exo-atmospheric Antiballistic missile	Altitude-120km	
Cruise Missiles				
Nirbhay	India	Subsonic cruise missile(Ship,submarine, aircraft and land).	1,000-1500 km	Mach 0.8
BrahMos	Russia & India	Supersonic cruise missile(Ship, submarine, aircraft and land)	290 km	Mach 2.8 to 3 Mach
BrahMos II	India	Hypersonic cruise missile(Ship, submarine, aircraft and land)	300km	Mach 7
Surface-to-surface missiles				
Agni-I	India	Medium-range ballistic missile (MRBM)	700-1250 km	Mach 7.5
Agni-II	India	Intermediate-range ballistic missile (IRBM)	2,000–3,000 km	Mach 12
Agni-III	India	Intermediate-range ballistic missile (IRBM)	3,500 km – 5,000 km	5–6 km/s
Agni-IV	India	Intermediate-range ballistic missile (IRBM)	3,000 – 4,000 km	Mach 7

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Agni-V	India	Intercontinental ballistic missile (ICBM)	5000 – 8000Km	Mach 24
Prithvi I	India	Short Range Ballistic Missile (Tactical)	150 km	
Prithvi II	India	Short Range Ballistic Missile (Tactical)	350 km	
Dhanush	India	Short Range Ballistic Missile (Tactical)	350 – 600 km	
Prahaar (Pragati)	India	Short Range Ballistic Missile (Tactical)	150 km	Mach 2.03
Shaurya	India	Medium-Range Ballistic Missile (MRBM)	750 to 1,900 km	Mach 7.5

Submarine Launched Ballistic Missiles				
Sagarika (K-15)	India	Ballistic Missile	700 – 1900Km	Mach 7+
K-4	India	Ballistic Missile	3,500–5,000 km	Mach 7+
K-5	India	Ballistic Missile	6,000 km	
Ashwin	India	Ballistic Missile	150-200km	Mach 4.5

Anti-Tank Missile				
Nag	India	Anti-Tank Guided Missile	4km	230 m/s
Helina (Helicopter launched NAG)	India	Anti-Tank Guided Missile	7-8km	
Amogha-1	India	Anti-Tank Guided Missile	2.8 km	

SCIENCE AND TECHNOLOGY IN ENERGY SECTOR

There are different sources of energy used in the world to generate power. All these different sources of energy are used primarily to produce electricity or electrical power that is sent out to different locations via high powered lines to be readily transformed in form of energy as required by the recipient.

Solar Energy : Solar energy is the primary source of energy of varied forms of energy in use.

Solar panels and power : Solar power is the energy harvested from the sunlight using collector panels called solar panels. Large solar panel fields are often used in desert to gather enough power to charge small substations and many homes use solar systems to provide for hot water, cooling and supplement their electricity. The issue with solar energy is that while there is plentiful amounts of sun available, only certain geographical ranges of the world get enough of the direct power of the sun for long enough to generate usable power from this source.

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Green building (Green construction or Sustainable building) : It refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition. The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

Wind Energy : In modern days, wind power is becoming more and more common. The new innovations that are allowing wind farms to become a more common sight. By using large turbines to take available wind as the power to turn and rotate a generator to produce electricity

Geothermal Energy : It is the energy produced from beneath the earth. It is clean, sustainable and eco-friendly. High temperatures are produced continuously inside the earth's crust by the slow delay of radioactive particles. Hot rocks present below the earth heats up the water that produces steam. The steam is then captured to move turbines which then power the generators to produce electricity.

The largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California, United States.

Hydrogen Energy : Hydrogen is the celestial source of energy. It is available with water and is most common element available on earth. Water contains two-thirds of hydrogen and can be found in combination with other elements. Once it is separated, with the highest calorific value can be used as a fuel for generating electricity.

Hydrogen is a tremendous source of energy and can be used as a source of fuel to power ships, vehicles, homes, industries and rockets. It is completely renewable can be produced on demand and does not leave any toxic emissions in the atmosphere.

Tidal Energy : Tidal energy uses rise and fall of tides to convert kinetic energy of incoming and outgoing tides into electrical energy. The generation of energy through tidal power is mostly prevalent in coastal areas. Huge investment and limited availability of sites are few of the drawbacks of tidal energy. Tidal energy is one of the renewable sources of energy and produce large energy even when the tides are at low speed.

Hydroelectric Energy : Today most of the cities and towns in the world rely on hydropower. In generation of hydroelectricity, the power of the water is used to rotate turbines and turn generators to produce the electricity.

The problems faced with hydropower right now have to do with the

- ecological imbalance
- fragmentation of human society on its construction at the most conducive site.
- aging of the already existent dams.

The drain on the world's drinkable water supply is also causing issues as townships may wind up needing to consume the water that provides them power too.

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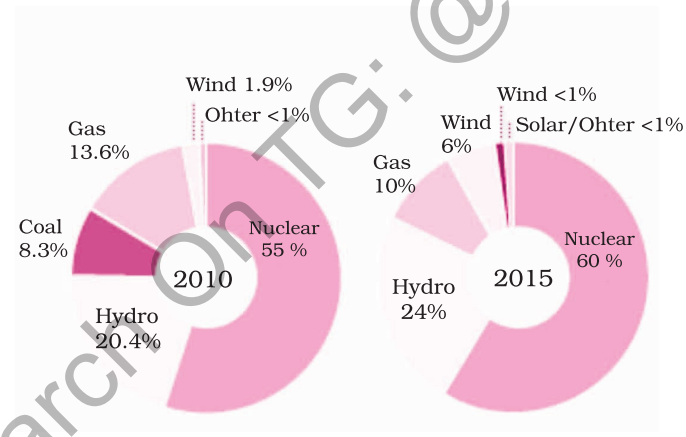
Nuclear Power: Although nuclear power remains a great subject of debate as to

- how safe it is to use
- whether or not, it is really energy efficient when looked into at amount and type of the waste produced ?

Yet the fact is that it remains one of the major renewable sources of energy available to the world. The energy is created through a specific nuclear fission reaction, which is then collected and used to power generators. While almost every country has nuclear generators, there are moratoriums on their use or construction as scientists try to resolve safety and disposal issues for radio active.

Fossil Fuels (Coal, Oil and Natural Gas) : For a laymen , the different sources of energy are natural gas, coal and oil. These are all considered to be just one source of energy from fossil fuels. Fossil fuels provide the power for most of the world, primarily using coal and oil. Crude oil is fractionally distilled and converted into many products, the most used of which is gasoline (Petrol). Natural gas is starting to become more common, but is used mostly for heating applications although there are more and more natural gas powered vehicles appearing on the roads. The issue with fossil fuels is two fold.



- To get to the fossil fuel and convert it to use there has to be a heavy destruction and pollution of the environment.
- The fossil fuel reserves are also limited, expecting to last only another 100 years given at the basic rate of consumption.

Hydrogen and fuel cells :

Hydrogen is an ideal replacement for fossil fuels in furnaces, internal combustion engines, turbines and jet engines.

Today, environmental pressures are concentrating hydrogen research and development efforts on hydrogen as an alternative fuel to power present mobility and transportation needs. In electrified vehicles, for example, it is used to run fuel cells which convert hydrogen efficiently (back) to electricity.

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Application of fuel cells

The application spectrum of fuel cells is vast. They have the potential to replace conventional power generators such as combustion engines or even large batteries in cars, buses, forklift trucks , submarines, and backup for power plants.

- Hydrogen-powered cars as many industrial partnerships have come in open to advance automotive electrification and reduce carbon emissions.
- Hydrogen-powered buses, in various cities including cities of North America and Europe, the fuelling infrastructure is developing fast to support H_2-powered public bus services.
- Hydrogen-based backup & off-grid power.
- Hydrogen-powered ships and submarines are now known to last longer. The submarines can remain under water for a longer time than conventional submarines and are much quieter.

Biogas as source of energy : Biogas is a mixture of about of 55-65 % methane (CH_4), 35-45 % carbon dioxide, 0.5-1.0 % hydrogen sulphide (H_2S) and traces of water vapor.

- In India, its practical application on experimental basis came in 1930 at Dadar, now in Mumbai by S. V. Desai and N. V. Joshi of the soil Chemistry Division , Indian Agricultural Research Institute, New Delhi.
- In 1960 , the development of biogas plants and their installation was taken over by Khadi and Villages Industries Commission (KVIC) to substitute the use of wood, coal or charcoal in rural areas.

Production of biogas : The biogas is created from anaerobic decaying of organic matter including sewage, animal byproducts, and agricultural, industrial, and municipal solid waste.

- The anaerobic digestion by microbiological activity of class of bacteria called *Methanogens* in the absence of air produce biogas.
- Chemical reactions involved in biogas production:

$$C_6H_{12}O_6 \longrightarrow 3CO_2 + 3CH_4$$

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

$$CH_3COOH \longrightarrow CH_4 + CO_2$$

Factors affecting optimum biogas production:

- Temperature (35-37^{0}C, Mesophilic condition)
- C/N ratio (optimum between 25:1 to 30:1)
- pH (optimally pH between 6.8-7.2)
- Solid content (feed material should have approx. 10:1)
- HRT (Hydraulic Retention Time – 30, 40, 55 days)

Characteristic features of biogas:

- It's average calorific value is 20 MJ/m^3 (4713 kcal/m^3).
- 28 cubic metres of biogas is equivalent to one domestic LPG cylinder.

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- Organic waste of 200 kg can contribute one LPG cylinder daily.
- 1 cubic metre of biogas can generate 1.5 units of electricity.

Uses of biogas:

- Biogas can be used in a specially designed burner for cooking purpose. A biogas plant of 2 cubic metres capacity is sufficient for providing cooking fuel needs of a family of about five person.
  - Family size biogas plants (1 to 10 m^3)
  - Large scale biogas plants (10 to 140 m^3)
  - Large scale plants above (1000 m^3) for industrial use or power generation.
- Biogas is used in silk mantle lamps for lighting purpose. The requirement of gas for powering a 100 candle lamp (60 W) is 0.13 cubic metre per hour.
- Biogas can be used to operate a dual fuel engine to replace up to 80 % of diesel-oil. Diesel engines have been modified to run 100 per cent on biogas. Petrol and CNG engines can also be modified to use biogas.
- Biogas after removal of CO_2, H_2S and water vapor can be converted to natural gas quality for use in vehicles.
- Biogas as a replacement for LPG or diesel makes economic feasibility for both cooking and power generation by urban and rural population, industry as well as households.

Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)

This scheme focuses on feeder separation (rural households & agricultural) and strengthening of sub-transmission & distribution infrastructure including metering at all levels in rural areas. The earlier scheme for rural electrification viz. Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) has been subsumed in the new scheme as its rural electrification component.

Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)

It was launched in April 2005 by merging all ongoing schemes. The Government is implementing Decentralised Distributed Generation (DDG) under RGGVY for electrification of villages where grid connectivity is either not feasible or not cost effective. In XII Plan period, DDG has also been extended to the grid connected area where supply of electricity is less than 6 hours a day. Decentralized Distributed Generation (DDG) can be from conventional or renewable sources such as Biomass, Biofuels, Biogas, Mini hydro, Solar etc. Rs.900 crore as subsidy has been earmarked for DDG projects.

Under the programme, 90% grant is provided by Govt. of India and 10% as loan by Rural Electrification Corporation (REC) to the State Governments. Rural Electrification Corporation (REC) is the nodal agency for the programme.

At present the aim is to

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- Electrify all villages and habitations as per new definition
- Provide access to electricity to all rural households
- Provide Electricity Connection to Below Poverty Line (BPL) families free of charge.

Remote Village Electrification Programme

The Ministry of New and Renewable Energy, Government of India is implementing this programme for providing financial support for electrification of those remote unelectrified census villages and unelectrified hamlets of electrified census villages where grid-extension is either not feasible or not cost effective and are not covered under Rajiv Gandhi Grameen Vidyutikaran Yojana. Such villages are provided basic facilities for electricity / lighting through various renewable energy sources. Small Hydro Power Generation systems, biomass gasification based electricity generation systems, solar photovoltaic power plants, etc., in distributed power generation mode may be used depending upon the availability of resources for generation of required electricity.

Village Energy Security programme

The objective of the project is to go beyond electrification by addressing the total energy requirements for cooking, electricity, and motive provide access to electricity through renewables to households in remote villages and hamlets, which are not likely to get covered through grid extension.

The projects on village energy security are taken up with a view to demonstrate the techno-economic parameters of the village energy security plan, provide operational experience, mobilize local communities and firm up the institutional arrangements.

The projects would be undertaken in unelectrified remote villages and hamlets that are not likely to be electrified through conventional means.

The projects would be undertaken by the Panchayats duly facilitated by implementing agencies such as DRDAs, forestry departments, NGOs, entrepreneurs, franchises, co-operatives, etc.

UDAY (Ujwal Discom Assurance Yojana)

It has presently been one of the most talked about schemes related to the Indian power sector. The scheme has been designed to look into the core of issues bugging the whole sector – the inefficient operation of the power distribution companies. As per the report from the ministry, of the 16 states, the part of the scheme, at least eight have a lower gap between their average cost of electricity supply and average cost of realisation and about 12 states have reduced their Aggregate Technical & Commercial (AT&C) loss levels. If successfully implemented, this policy can permanently solve the long-standing issues of the distribution sector and revive energy demand of the country.

EESL(Energy Efficiency Service Ltd)

It was formed with the task of creating the market for Energy Efficiency through a business plan and not be dependent on Government

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subsidies. It has taken a huge turn with nearly 180 million LED Bulbs and 1.5 million LED Street Lights having been distributed already and many other energy efficiency products are on the way to create self-sustaining and low cost energy efficiency market in India.

WiTricity

"Wireless electricity technology with aim to forge toward a "wire-free world," is coming to mobile devices, electric vehicles, and potentially a host of other applications such as charging laptops, 2-in1 computers and tablets.

Recently Intel has took to integrate WiTricity technology into computing devices powered by Intel while Toyota licensed WiTricity technology for a future line of electric cars. There's even talk of a helmet powered wirelessly via backpack, specifically for military applications.

IT and Government of India

The Ministry of Communication and Information Technology was a Ministry under government of India. In July 2016, it was bifurcated into Ministry of Communications and Ministry of Electronics and Information Technology . It contained three departments viz. Department of Telecommunications, Department of Electronics and Information Technology (Deity) and Department of posts..

Ministry of Electronics and Information Technology (MeitY)

Vision : "e-Development of India as the engine for transition into a developed nation and an empowered society"

Mission :

- To promote e-Governance for empowering citizens
- To promote the inclusive and sustainable growth of the Electronics, IT & ITeS industries.
- To enhance India's role in Internet Governance, adopting a multi-pronged approach that includes development of human resources, promoting R&D and innovation
- To enhance efficiency through digital services in a secure cyber space.

Objectives :

e-Government : Providing e-infrastructure for delivery of e-services

e-Industry : Promotion of electronics hardware manufacturing and IT-ITeS industry

e-Innovation / R&D : Implementation of R&D Framework - Enabling creation of Innovation/ R&D Infrastructure in emerging areas of ICT&E/ Establishment of mechanism for R&D translation

e-Learning : Providing support for development of e-Skills and Knowledge network

e-Security : Securing India's cyber space

e-Inclusion : Promoting the use of ICT for more inclusive growth

Internet Governance : Enhancing India's role in Global Platforms of Internet Governance.

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Autonomous Societies of MeitY

- Education and Research in Computer Networking (ERNET)
- Centre for Development of Advanced Computing (C-DAC)
- Centre for Materials for Electronics Technology (C-MET)
- National Institute of Electronics and Information Technology (NIEL-IT) — Formerly DOEACC Society
- Society for Applied Microwave Electronics Engineering and Research (SAMEER)
- Software Technology Parks of India (STPI)
- Electronics and Computer Software Export Promotion Council (ESC)

Main Technological hubs in India : Today, Bangalore is known as the Silicon Valley of India and contributes 38% of Indian IT Exports. India's second and third largest software companies are headquartered in Bangalore, as are many of the global Companies. Cities like Hyderabad, Chennai, Pune and Gurgaon are also emerging as technology hubs, with many global IT companies establishing headquarters there. Numerous IT companies are also based in Mumbai.

Software Technology Parks of India (STPI) : It is a society established in 1991 by the Indian Ministry of Communications and Information Technology with the objective of encouraging , promoting and boosting the export of software from India.It maintains its own internal engineering resources to provide consulting, training and implementation services.

Services provided by STPI : These serves cover network design, system integration, installation, operations and maintenance of application networks and facilities in varied areas.

Advantages : STPI is an export oriented scheme for the development and export of computer software, including export of professional services.

- The STPI Scheme provides various benefits to the registered units, including 100% foreign equity, tax incentives, duty-free import, duty-free indigenous procurement, CST reimbursement, DTA entitlement, and deemed exporting.
- STPI plays an important role in India having earned a reputation as an information technology superpower.
- STP units exports software and information technology worth in crores per annum. The states with the largest export contribution are Karnataka, Hyderabad, Maharashtra, Tamil Nadu and Telangana.
- Besides regulating the STP scheme, STPI centers also provide a variety of services including high-speed data communication, incubation facilities, consultancy, network monitoring, data centers and data hosting. STPI provides physical hosting for the National Internet Exchange of India.

STPI has a presence in many of the major cities of India including the cities of Bangalore, Chennai, Hyderabad, Kanpur, Kolkata, Mumbai, Nagpur, Lucknow, Pune and Surat in Gujarat.

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DIGITAL INDIA

Digital India is a campaign launched by the **Government of India** in June, 2015 by the Prime Minister to ensure that Government services are made available to citizens electronically by improved online infrastructure and by increasing Internet connectivity or by making the country digitally empowered in the field of technology. Digital India consists of three core components.

- The creation of digital infrastructure
- Delivery of services digitally
- Digital literacy

The overall scope of the programme 'Digital India' is:

- To prepare India for a knowledgable future.
- On being transformative that is to realize
  IT (India Tomorrow) = IT (Indian Talent) + IT(Information Technology)
- Making technology central to enabling change.
- On being an Umbrella Programme-covering many departments.

The initiative includes plans to connect rural areas with high-speed internet networks. Although many steps have so far been taken in fulfilling the vision " Power To Empower". Some of these considered as major are:

Aadhaar : It is an identity platform, one of the key pillars of 'Digital India', wherein every resident of the country is provided with a unique identity (Aadhaar number). It is important for being

- The largest biometrics based identification system in the world,
- As a strategic policy tool for social and financial inclusion, public sector delivery reforms, managing fiscal budgets, increase convenience and promote hassle-free people-centric governance.
- Eliminating duplicate or fake identities being used as a basis/ primary identifier to roll out several Government welfare schemes and programmes for effective service delivery thereby promoting transparency and good governance.

Accessible India Campaign Mobile : Accessible India Campaign (Sugamya Bharat Abhiyaan) is a nation-wide flagship campaign for achieving universal accessibility that enables people with disabilities to gain access for equal opportunity, live independently and participate fully in all aspects of life in an inclusive society. The campaign targets at enhancing the accessibility of built environment, transport system and Information and communication ecosystem.

e-Granthalaya : e-Granthalaya is an Integrated Library Management Software developed by National Informatics Centre, DEIT. The application is useful for automation of in-house activities of libraries and to provide various online member services. The software provides built-in Web OPAC interface to publish the library catalogue over Internet. The software is UNICODE Compliant, thus, supports data entry in local languages too.

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e-Basta: In the Government's Digital India initiative, the project has created a framework to make school books accessible in digital form as e-books to be read and used on tablets and laptops. The main idea is to bring various publishers (free as well as commercial) and schools together on one platform.

National Ujala Dashboard: In Government of India's efforts to spread the message of energy efficiency in the country., UJALA scheme has come as an initiative to promote efficient use of energy at the residential level; enhance the awareness of consumers about the efficacy of using energy efficient appliances and aggregating demand to reduce the high initial costs thus facilitating higher uptake of LED lights by residential users.

Single Window Interface for Trade (SWIFT) : In effort of "Ease of Doing Business" initiatives, the Central Board of Excise & Customs, Government of India has taken up implementation of the Single Window Project to facilitate the Trading Aross Borders in India. It would allow importers and exporters, the facility to lodge their clearance documents online at a single point only. Required permissions, if any, from other regulatory agencies would be obtained online without the trader having to approach these agencies. The Single Window Interface for Trade (SWIFT), would reduce interface with Governmental agencies, time and the cost of doing business.

BIOTECHNOLOGY IN MEDICAL SCIENCES

Doctors use tests to communicate with the patient, observe his or her body, and support their diagnosis. Many tests are now available to practitioners. They may indicate the presence of a germ or abnormal cells, or the lack or excess of certain chemicals. Genetic tests now detect disease present in the body. They even detect risk factors which indicate the likelihood of a healthy person developing a disease such as breast cancer later in life.

List of different medical tests for imaging

Technique	Procedure and applications
Radiography	Two forms of radiographic images are in use in medical imaging. Projection radiography and fluoroscopy. Fluoroscopy: It produces real-time images of internal structures of the body in a similar fashion to radiography, but employs a constant input of X-rays, at a lower dose rate. Contrast media, such as barium, or iodine, is used to visualize internal organs as they work. Projectional radiographs : It more commonly known as X-rays, are often used to determine the type and extent of a fracture as well as for detecting pathological changes in the lungs. With the use of radio-opaque contrast media, such as barium, they can also be used to visualize the structure of the stomach and intestines - this can help diagnose ulcers or certain types of colon cancer.

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Magnetic resonance imaging	A instrument (MRI scanner), or "nuclear magnetic resonance (NMR) imaging" scanner uses powerful magnets to polarize and excite hydrogen nuclei (i.e., single protons) of water molecules in human tissue, producing a detectable signal which is spatially encoded, resulting in images of the body. The MRI machine emits a radio frequency (RF) pulse at the resonant frequency of the hydrogen atoms on water molecules. Radio frequency antennas send the pulse to the area of the body to be examined. The RF pulse is absorbed by protons, causing their direction with respect to the primary magnetic field to change. When the RF pulse is turned off, the protons "relax" back to alignment with the primary magnet and emit radio-waves in the process. This radio-frequency emission from the hydrogen-atoms on water is detected and reconstructed into an image.
Scintigraphy ("scint")	It is a form of diagnostic test wherein radioisotopes are taken internally, for example intravenously or orally. Then, gamma cameras capture and form two-dimensional images from the radiation emitted by the radiopharmaceuticals.
SPECT	It is a 3D tomographic technique that uses gamma camera data from many projections. It has shown utility in advancing the field of molecular imaging.. In SPECT imaging, the patient is injected with a radioisotope, most commonly Thallium 201Tl, Technetium 99mTC, Iodine-123, and Gallium-67. The radioactive gamma rays are emitted through the body as the natural decaying process of these isotopes takes place. The emissions of the gamma rays are captured by detectors that surround the body. This essentially means that the human is now the source of the radioactivity, rather than the medical imaging devices such as X-Ray or CT.
Positron emission tomography (PET)	It uses coincidence detection to image functional processes. Short-lived positron emitting isotope, such as ^{18}F, is incorporated with an organic substance such as glucose, creating F18-fluorodeoxyglucose, which can be used as a marker of metabolic utilization. Images of activity distribution throughout the body can show rapidly growing tissue, like tumor, metastasis, or infection. PET images can be viewed in comparison to computed tomography scans to determine an anatomic correlate.

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Medical ultra - sonography	It uses high frequency broadband sound waves in the megahertz range that are reflected by tissue to varying degrees to produce (up to 3D) images. This is commonly associated with imaging the fetus in pregnant women.. Other important uses include imaging the abdominal organs, heart, breast, muscles, tendons, arteries and veins,
Elastography	It is a relatively new imaging modality that maps the elastic properties of soft tissue. Elastography is useful in medical diagnosis, as elasticity can discern healthy from unhealthy tissue for specific organs/growths. For example, cancerous tumours will often be harder than the surrounding tissue, and diseased livers are stiffer than healthy ones.
Tactile imaging	It is a medical imaging modality that translates the sense of touch into a digital image. The tactile image is a function of P(x,y,z), where P is the pressure on soft tissue surface under applied deformation and x,y,z are coordinates where pressure P was measured. This modality is used for imaging of the prostate, breast, vagina and pelvic floor support structures, and myofascial trigger points in muscle.
X-ray computed tomography (CT), or Computed Axial Tomography (CAT) Scan	It, is a helical tomography technique (latest generation), which traditionally produces a 2D image of the structures in a thin section of the body. In CT, a beam of X-rays spins around an object being examined and is picked up by sensitive radiation detectors after having penetrated the object from multiple angles. A computer then analyses the information received from the scanner's detectors and constructs a detailed image of the object and its contents using the mathematical principles laid out in the Radon transform. CT is based on the principles as X-Ray projections but in this case, the patient is enclosed in a surrounding ring of detectors assigned with 500-1000 scintillation detectors(fourth-generation X-Ray CT scanner geometry). Previously in older generation scanners, the X-Ray beam was paired by a translating source and detector.

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Echocardiography	When ultrasound is used to image the heart it is referred to as an echocardiogram. Echocardiography allows detailed structures of the heart, including chamber size, heart function, the valves of the heart, as well as the pericardium (the sac around the heart) to be seen. Echocardiography uses 2D, 3D, and Doppler imaging to create pictures of the heart and visualize the blood flowing through each of the four heart valves. Echocardiography is widely used in an array of patients ranging from those experiencing symptoms, such as shortness of breath or chest pains, to those undergoing cancer treatments.

CT and MRI :

- Like CT (CAT Scan), MRI creates a two dimensional image of a thin "slice" of the body and is therefore considered atomographic imaging technique. Modern MRI instruments are capable of producing images in the form of 3D blocks, which are considered generalization of the single-slice, tomographic, concept unlike CT.
- MRI does not involve the use of ionizing radiation and is therefore not associated with the same health hazards. Therefore, there is no limit to the number of scans to which an individual can be subjected, in contrast with X-ray and CT.
- CT and MRI are sensitive to different tissue properties, the appearance of the images obtained with the two techniques differ markedly. In CT, X-rays must be blocked by some form of dense tissue to create an image, so the image quality when looking at soft tissues will be poor. In MRI allows the excellent soft-tissue contrast.

A number of different pulse sequences can be used for specific MRI diagnostic imaging such as in imaging of prostate tumors , liver studies, breast tumors, pancreatic tumors, and assessing the effects of vascular disruption agents on cancer tumors.

Ethical issues in medical sciences : Ethical issues such as immediate health risks and later consequences must be considered when using medical tests. The prenatal amniocentesis of fluid to investigate the presence of genetic disorders in the foetus carries a small risk of miscarriage. Parents and practitioner must consider this risk. What are the consequences of knowing the outcomes of a test? When does it benefit the patient to know of the presence of risk factors? Early indication of the presence of risk factors may help patients change their lifestyles. This minimises their chances of developing the condition for which they are at risk. However, knowledge of the presence of risk factors may diminish a person's quality of life.

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Chapter 1

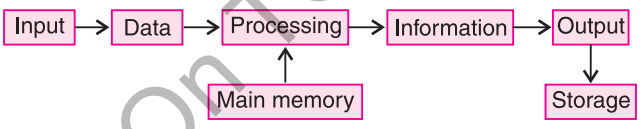
COMPUTER KNOWLEDGE

COMPUTER : AN INTRODUCTION

Computer today has become an integral part of our lives. Infact today, we are living in the age of Information Revolution which is much to be owed, to the ability of computers of disseminating information at an incredible speed. From education to entertainment and from communication to business, computers are present every where. Thus in this era of Information, it is crucial to have the basic knowledge of computer, its parts, its components and its application in a variety of fields. A sound theoretical base of computer and its applications enhances the knowledge level of the reader to make the journey in the colourful world of computers, an exhilarating one.

Calculator : A device that performs mathematical operations but it has no storage capacity.

Computer : A device that works *in* electric medium and performs both mathematical and logical operations with storage capacity. It's basic functions can be summerized as follows.



FUNCTIONING OF COMPUTER

Binary System

- Zero and one in their endless combination constitute binary system on which is based the working of computers.
- Under the binary system all ordinary arithmetical operations are reduced to their simplest form. The binary system of numeration was used early in the 17th century by Thomas Harriot.
- The binary numbers for the following numbers are written as 0-0, 1-1, 2-10, 3-11, 4-100, 5-101, 6-110, 7-111, 8-1000, 9-1001, 10-1010,11-1011, 15-1111, 16-10000.

CLASSIFICATION OF COMPUTERS

Computers can be classified into five types :

- Portable Computer : These are the computers which can be carried from one place to another in the form of a briefcase or diary. It includes Laptop, Notebook and Personal Digital Assistant (PDA).

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- Micro Computer : These are single user computers often called as Personal Computers (PCs). The home computer is a PC providing education, entertainment, information and communication facility at home.
- Mini Computer : They are medium level, multiuser computers. As compared to Mainframe Computers, these computers operate at slower speeds and have lesser memory. These are used by Insurance companies, Bank, Factories for keeping the records.
- Mainframe Computer : These are expensive, large centralised computers. With large memory, these are capable of having speeds of the order of several billions of floating-point-operations per second. These computers help in railway reservation and such other operations.
- Super Computer : These are extensively used computers for solving very large computational problems in scientific research, engineering, industry, defence and business for variety of applications like molecular dynamics, aerospace, nuclear-weapon, seismic studies, oil-explorations, geology etc. ANUPAM, Cray-1, Param Padma are some of known super computers.

TYPES OF COMPUTERS BASED ON DATA TAKEN and OUTPUT

(i) Analog : It recognises data as continuous measurement in wave form by continuous electrical pulses.

(ii) Digital : The computers count data or signals as "on" or "off" in binary digits only.

(iii) Hybrid : Computer that exhibit features of analog computers and digital computers. The digital component normally serve as the controller and provides logical operations while the analog component normally serve as a solver of differential equations. Eg : HRS-100, Computers in Hospitals.

Evolution of Computer

- ABACUS : It is the first computer introduced in 2000 BC
- 1642 : Blaise Pascal invented PASCAL's calculator
- 1801 : Joseph Jaquard introduced Punched cards that were used in Cotton looms and Weaving patterns to store data. It is considered an important step in the history of computing hardware.
- 1823 - 34 : Charles Babbage also called father of Computers, in 1822 developed different engine, made to compute values of polynomial functions. Babbage worked to design a more complex machine called the Analytical Engine.
- ENIAC : Electronic Numeric Integrator and Calculator. First commercial electronic Computer.
- In 1971, the Intel 4004 world's first single chip micro processor was invented by Intel engineers Federico Faggin, Marcian Ted Hoff and Stanley Mazor.

  Since, first electronic computers was invented in 1940's, the generation of computer start from here.

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Computer Generations

Generation	Years	Chief Components	Memory Elements	Operating System	Language	Examples
Ist	1940-55	Vacuum Tubes/ Electronic valves for circuitry	Magnetic drums for memory	No	Machine language (Lowest-level programming language)	ENIAC EDSAC EDVAC UNIVAC
2nd	1956-63	Transistors (invented in 1947)	Magnetic cores Magnetic Tapes	No	Assembly Language, High level language e.g, FORTRAN, COBOL	IBM 700/1401 IBM 7030
3rd	1964-71	Integrated Circuits (semi con-ductors were used)	RAM, DISKS	LINUX	ALGOL C, C++ JAVA SQL	CDC 6600/760 IBM 360 IBM 370 CRAY-1
4th	1972-Present	LSI (Large Scale Integration)/ VLSI (Very Large Scale Integration)	All Primary, Secondary Storage devices	Windows DOS, LINUX	SQL ORACLE	All PC's & Desktops, CRAYX-MP
5th	Development Phase	Artificial Intelligence, Robotics & Nano Science	Some application such as voice recognition that are being used today are based on artificial intelligence.			

Artificial Intelligence : The Intelligence (science) involved and used by machines to perform the human activities such as writing, reading and all the human activities.

Nano Science : The Science / technology that involves observation and deals with studying particles of size 10^{-10}m . The term 'nano' refers to the metric prefix 10^{-9}.

Robotics : The Sensitive operations in human body are performed through Rod like structures that acts according to machine instructions and the technology is called Robotics.

IMPORTANT DEVELOPMENTS IN THE FIELD OF COMPUTER

e-WORLD

(i) e-book : An electronic small book published in a format portable with all the features of a print version.

(ii) e-paper : It is a portable, reusable storage and display medium that can be repeatedly written several times.

(iii) e-library :- It is a virtual library that stores and delivers exclusive content, collection of articles, reports, features and tools.

(iv) e-tailware :- It is the software for creating on-line catalogues, ordering forms, credit checking and similar services for Web sites that sell goods and services to consumers.

(v) e-mail :- 'Electronic mail', it is the act of sending and receiving messages through internet.

(vi) e-governance :- It is the application of IT and to the process of government functioning. Its objective is to provide speedy, responsive and transparent governance. Various e-governance projects have been launched in India. These include, 'Gyandoot' (Madhya Pradesh), 'FRIENDS' (Kerala), 'AKSHAYA', (Kerala).

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COMPUTER ABBREVIATIONS

- ALU : Arithmetic Logic Unit.
- ASCII : American Standard Code for Information Interchange.
- BPS : Bit Per Second.
- CARP : Cache Array Routing Protocol.
- C-DAC : Centre for Development of Advance Computing.
- C-DOT : Centre for Development of Telematics.
- DBMS : Data Base Management System.
- DIP : Dial-up Internet Protocol.
- DOS : Disk Operating System.
- DRAM : Dynamic Random Access Memory.
- FLOPS : Floating Point Operations Per Second.
- FSP : File Service Protocol.
- GSM : Global System for Mobiles.
- GUI : Graphical User Interface.
- HDLC : High Level Data Link Control.
- HID : Human Interface Device.
- HTTPS : Hypertext Transfer Protocol Secure.
- IP : Internet Protocol.
- IPP : Internet Printing Protocol.
- KBPS : Kilobits Per Second.
- LAWN : Local Area Wireless Network.
- MAN : Metropolitan Area Network.
- MB : Mega Bytes.
- Mbps : Mega bits per second.
- MCB : Memory Control Block.
- MIPS : Millions of Instruction Per Second.
- MIS : Management Information System.
- MMX : Multimedia Extension.
- NASDAQ : National Association of Securities Dealers Automated Quotation.
- NAT-PT : Network Address Translation-Protocol Translation.
- NETBIOS : Network Adapter Basic Input Output System.
- PAP : Password Authentication Protocol.
- PCM : Pulse Code Modulation.
- PDN : Public Data Network.
- PIN : Personal Identification Number.
- PRISM : Parallel Reduced Instruction Set Multiprocessing.
- PROM : Programmable Read Only Memory.
- RAM : Random Access Memory.
- SIM : Subscriber Identification Module.
- SLIP : Serial Line Internet Protocol.
- SQL : System Query Language.

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- SWAP : Superior Wireless Application.
- SYSOP : System Operator.
- TCP/IP : Transmission Control Protocol/Internet Protocol.
- TFLOPS : Tera Floating-Point Operations Per Second.
- VOIP : Voice Over Internet Protocol.
- WSDL : Web Services Description Language.
- ZIP : Zone Information Protocol.

COMPUTER TERMINOLOGY

- Assembly Language : It is a low-level language which uses mnemonic statements to generate machine code. It is typified by its speed of execution and small executable file size. They are hardware specific and therefore programme written on one particular machine may not work on another.
- Advanced Technology Attachment Packet Interface (ATAPI) : A standard that makes it very easy to connect a CD-ROM drive to an Enhanced IDE host adapter.
- Analog : Describes a system, particularly an electronic device, that uses a continuous physical quantity to represent information.
- API (Application Programming Interface) : API is a method prescribed by a computer operating system or an application programme which a programmer who is writing an application programme can use to make requests of the operating system or another application.
- ASCII : American Standard Code for Information Interchange. This is a de-facto worldwide standard for code numbers used by computers to represent all upper and lowercase English letters, numbers, punctuation, etc.
- Beginner's All-Purpose Symbolic Instruction Code (BASIC) : An easy to use high level programming language which is now replaced by improved version of Microsoft Visual Basic.
- Basic Input/Output System (BIOS) : A set of programmes encoded in Read Only Memory (ROM) in IBM PC-compatible computers. These programmes handle start up operations and low-level control for hardware such as key boards, monitor and diskdrives.
- Boot : An initiating automatic routine that is read into RAM when a computer is first turned on. The process of starting the computer is called boot and restarting is called warm boot.
- Bits per inch (bpi) : In magnetic media such as backup tape drives or disk drives, the measurement of the media's recording density is done in bpi.
- BOPS : Billions Operations Per Second.
- BANDWIDTH : The amount of data that can flow through a channel. The higher the bandwidth, the more is data that can travel at a time.
- Binary File : A file containing information such as a program, compressed archive, an image or a document etc. The contents of the file generally can't be displayed or printed without using some program.
- Browser : Browser is a client software that allows the user to display and interact with a hypertext document i.e., it is a client software which helps users to navigate the www.

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- Bus : A bus is a transmission path on which signals are dropped off or picked up by devices that are attached to it.
- C : C is a programming language that has been widely used for operating systems and applications. Many versions of UNIX- based operating systems are written in C.
- C++ : C++ is an object-oriented version of the popular C programming language. It combines the C language features with object-oriented capabilities. It has been adopted as the in-house programming language of a number of companies like Sun Microsystems and Apple Computers.
- CAD (Computer-Aided Design) : CAD is a software used by architects and engineers to create technical drawings
- CASE (Computer-Aided Software Engineering) : CASE is a computer-assisted method to organise and control software development. It allows the designers, code writers, testers, planners and managers to share a common view of where the project stands.
- COBOL (Common Business-Oriented Language) : COBOL was the first high-level programming language for business applications. Over the past 35 years, many payroll, accounting and other business applications have been written in COBOL.
- Cyber Space : Cyber means to steer guide or control. It means the global pool of information held on computer networks, connected together by sophisticated transmission technology, that can be accessed by anyone.
- Cache : It is a memory storage area that keeps frequent use data readily available to the computer so that the Computer does not retrieve them from slow storage devices.
- Computer Aided Design (CAD) : A CAD programme is used to design a wide ranging industrial products, ranging from machine parts to home using computer.
- Computer Aided Design and Drafting(CADD) : It is used for industrial design and technical drawing. It is similar to CAD except that it has additional features that enable the user to produce drawing conforming to engineering conventions.
- Computer Aided Software Engineering (CASE) : The use of software package to

  CD : Compact Disc.

  CD-DA : Compact Disc-Digital Audio.

  CD-I : Compact Disc-Interactive.

  CD-R : Compact Disc- Recordable.

  CD-RW : Compact Dist-Rewritable.

  CPU : Central Processing Unit.

  CGI : Common Gateway Interface.

  CHAT : Conversational Hypertext Access Technology.
- Clock Speed : The speed of computer measured in Mega Hertz(MHz)is clock speed.
- Com : In MS-DOS, Com is a device name that refers to the serial ports available in the computer. A computer can have upto four Comports designated as COM1,COM2, COM3 and COM4.

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- Computer Virus : A programme designed as a prank or as sabotage that replicates itself by attaching to other programmes and carrying out unwanted and sometimes dangerous operation. Internet technologies have made the 'connected' computer more vulnerable to be attacked by virus.
- DBMS : (Database Managements Systems) : An application programme that provides the tool for data retrieval, modification, deletion and insertion.
- Defragmentation : A procedure in which all files on a hard disc are re–written on disc so that all parts of each file are written to contiguous sectors. This is done to improve the speed of computer.
- Desktop Computer : A personal computer or professional workstation designed to fit on standard office desk that's equipped with sufficient memory and disk storage to perform business computing tasks.
- Digital Signature : An encrypted tamper-proof attentation that is usually attached to encrypted e-mail message or certificate.
- DOS : Disc Operating System.
- Dial-up access : Access to the Internet through a telephone line and a modem.
- Digital : Digital technology generates, stores and processes data in terms of two states: positive and non–positive. Data that is transmitted or stored with digital technology is expressed as a string of 0s and 1s. It is mainly used with new communication media, such as satellite and fibre optic transmission.
- Download/Upload : To download is to transfer a file from another computer to the user's computer. To upload is to send a file to another computer.
- EAROM : Electrically Alterable Read Only Memory.
- EDI (Electronic Data Interchange) : A standard for the electronic exchange of business documents such as invoices and purchase orders.
- EGA : Enhanced Graphics Adapter.
- XML : Extensible Markup Language.
- Ethernet : It is the most popular type of LAN, in which communications through radio frequency signals is carried by a co-axial cable. Software protocols used by Ethernet Systems vary, but include TCP/IP and Navel Netware.
- Ethernet Card : A network adapter that enables a computer to connect to an Ethernet. It is a printed circuit board that is in built or mother-board or is plugged on computer which is on Ethernet.
- Extranet : An Intranet (Internal TCP/IP network) that has been selectively opened to a firm's suppliers, customers and strategic allies.
- FDD : Floppy Disk Drive.
- FAX : Facsimile (Far Away Xeroz) used to send printed pages between two location using telephone lines.
- FLOP (Floating point operations per sec) : This is the unit of measurement of the speed at which computer carries out floating point operations.
- File Transfer Protocol (FTP) : A client/server protocol for exchanging files with a host computer.

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- File Allocation Table (FAT) : It is a hidden file located in sector 0 on a floppy/Hard disk. It contains information about the sizes of files stored and that cluster contains which file.
- Green PC : A computer system designed to operate in energy efficient manner.
- Graphical User Interface (GUI) : A design for the part of program that interacts with the user and that uses icons/graphic representations to represent programme features.
- Greeking : The use of symbols to show text or graphics that cannot be shown in sufficient detail for the whole document to be legible is called greeking.
- HPC : Handheld Personal Computer
- HFS (Hierarchial File System) : In an operating system a method of organising files in tree structure. The topmost level called root directory which contains leaves called sub-directories which further contain sub-directors. Such a file systems is called HFS.
- HTML (Hyper Text Markup Language) : It is markup language behind the appearance of documents on the World Wide Web (WWW).
- HTTP (Hyper Text Transfer Protocol) : The protocol most often used to transfer information form WWW server to browsers, which is why web addresses begin with http://
- HTTPS (Hyper Text Transfer Protocol Secure) : A variation of HTTP that provides special security for online transaction on WWW.
- IBM : International Business Machine.
- ICMP (Internet Control Message Protocol) : It is an extension to the original Internet Protocol that provides much needed error and congestion control.
- IMAP (Internet Message Access Protocol) : IMAB is one of the two fundamental protocols in the internet e-mail (other being PCP3) that governs how and where user stores their incoming mail messages. In IMAP, mails are stored on the mail server.
- IANA (Internet Assigned Numbers Authority) : A unit of Internet Architecture Board (IAB) that supervises the allocation of IP (Internet Protocol) addresses, port address and other numerical standards on the Internet.
- IP (Internet Protocol) : In TCP/IP, IP is the connectionless part of TCP/IP protocols.
- IP Address : A 32-bit binary number that uniquely and precisely identifies the location of a particular computer on the Internet.
- ISP : Internet Service Provider.
- JDK : Java Development Kit is a package of Java utilities and development tools created by Sun Microsystems. It represents the de facto standard for the Java Programming language.
- JPEG (Joint Photographic Experts Group) : A graphics format that is ideal for complex pictures/graphics.
- LCD (Liquid Crystal Display) : It is a low-power display technology used in laptop computers.
- LED (Light Emitting Diode) : A small electronic device made from semiconductor materials.

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- LINUX : An operating system designed by Linus Torvalda.
- MODEM (Modulator Demodulator) : A device that converts the digital signals generated by the serial port to the modulated analog signals required for transmission over a telephone line and likewise transforms incoming analog signals to their digital equivalents.
- MIDI (Musical Instrument Digital Interface) : A standard communications protocol for the exchange of information between computers and musical synthesisers.
- PAN : Personal Area Network
- PDF (Portable Document Format) : It is a file extension/a portable document file format created by Adobe Systems.
- P-Mail : Paper Mail.
- POST (Power on Self-Test) : It is internal testing which is performed when the computer is started or reset. Encoded in ROM, the POST program first checks the microprocessor by having it perform a simple operations.
- PROM : Programmable Read-Only Memory.
- PIN (Personnel Identification Number) : It is a digital number used for accessing highly secure information.
- Protocol : In computer terminology, it is a set of rules or standard designed so that computers can exchange information with a minimum of error.
- Random Access Memory (RAM) : It is computer's primary working memory in which program instructions and data are stored so that they can be accessed directly by the CPU via processor's high speed external data bus. RAM is often called Read/Write Memory. In RAM-CPU can read and write data. RAM does not retain its contents when the power to the computer is switched off.
- Read Only Memory (ROM) : It is the portion of computers storage that does not lose its contents when one switches off the computer. ROM contains essentials system programmes that cannot erased.
- Rich Text Format (RTF) : A text formatting standard developed by Microsoft that allows the word processor to create file with some of the formatting instructions.
- Ripper : A programme that can extract audio tracks from audio CD's and write these to computer's hard disk. It is also called CD ripper.
- Scandisk : A Window utility that checks magnetic disks (Floppies and Hard Disk) for errors such as lost clusters and file system irregularities.
- SLIP (Serial Line Internet Protocol) : It defines the transport of data packets through an asynchronous telephone line. Therefore, SLIP enables computers not directly connected to LANs to be fully connected to the Internet.
- SMTP (Simple Mail Transport Protocol) : It is an Internet protocol that governs the transmission of e-mail over computer networks. It does not provide any support for transmission of data other than plain text.

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- Spoder : A utility programme, often included with an operating system that routes printer commands to a file on disk or in RAM rather to a printer, and then doles out the printer commands when CPU is idle.
- SMS : Short Messaging Service.
- SVGA (Super Video Graphics Array) : It is an enhancement of VGA (Visual Graphics Array) so as to obtain better picture.
- Telephony Application Programme Interface (TAPI) : It is a set of standard programming functions that can be implemented by application that interface with telecommunication equipment.
- Tunnelling : It is a mechanism of forwarding traffic from remote users to a corporate network through an existing public IP network. Data is encapsulated within an IP datagram and then decapsulated at the other endpoint of the tunnel.
- Trunk : It refers to aggregation of multiple telecom lines or virtual local area networks to increase a bandwidth.
- Terminator : It is an electrical impedance attached to the open end of a transmission line to eliminate reflections.
- Telemedicine : The provision of high quality, up-to-date medical information to medical practitioners.
- TIF : TIF files are often used to hold scanned photographic images.
- Transducer : A device that converts a detectable physical phenomenon such as sound, pressure, or light into electronic signals that can then be processed by computer.
- Trojan Horse : A programme that appears to perform a valid function but has some hidden instructions in its code that can cause severe damage to the system on which the programme runs. Unlike computer virus, Trojan horse cannot replicate themselves.
- TELNET : A terminal emulation protocol that lets a user lag in remotely to other computers on the Internet.
- UPS (Uninterruptible Power Supply/System) : A battery system that can supply continuous power to a computer in the event of power failure for some time (approx. 10-15 minutes) after supply loss.
- URL (Uniform Resource Locator) : In the World Wide Web (WWW), it is one of the two basic kind of Uniform Resource Identifier (URL). It is string of character that precisely define an Internet resource's type and location.
- URI (Uniform Resource Identifier) : In the HTTP, a string of characters identifies an Internet resource of WWW including the type of resource and its location. There are two types of URIs. Uniform Resource Locators (URLs) and relative URLs (RELURL).

  In RELURL string of character gives only the file name and does not specify its location or type. Web Browser (as Parsers) resource.
- V Disk (Virtual Disk) : It's a storage technique in which the complete storage disk (CD etc.) can be copied to hard disk. The virtual disk of storage disk acts similar to the original disk.
- W3 (WWW) (World Wide Web) : A global hypertext system that uses the Internet as its transport mechanism.
- WAV (Waveform Audio) : File name extension for audio-files.

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- WORM (Write Once Read Many) : An optical disk drive with storage capacities of upto 1 TB. After once writing the data the disk drive becomes Read Only storage medium. WORM is used to keep large database.
- ZIP : Compressed file (File Name Extension).
- Quantum Computers : It is a device that harnesses physical phenomena unique to quantum mechanics to realise a fundamentally new mode of information processing. In it, the fundamental unit of information (qubit) is quarternary in nature.
- Analog Transmission : It refers to the signal transmission over wires or through the air. The information is sent and received by combining amplitude, frequency and phase signals.
- Worm : A worm is a virus that does not infect other programme. It makes copies of itself, and infects additional computers (typically by making use of network connections).
- Password : A code used to gain access (login) to a locked system. Good passwords contain letters and non-letters and are not simple combination such as Virtue 7.
- Piracy : The illegal copying of software.
- Roaming : The ability to use a communication device such as a cellphone or personal digital assistants and be able to move from one cell or access point to another without losing the connection.
- Swapping : It is the process of replacing one segment of a programme in memory with another and restoring it back to the original when required.
- Intranet : A private network inside a company or organisation using same software.
- Finger : An Internet software tool for locating people on other Internet sites.
- Browser : It is a client programme (software) that is used to log at various kinds of Internet resources.
- Backbone : A high speed line or series of connections that forms a major pathway within a network, is known as backbone.
- Cyber Space : The virtual community created by the information society, which has removed all physical demarcations, geographical boundaries and political limitations is known as the Cyber space.
- Netizens : Citizens having access to Internet are called netizens.
- Ethernet : A type of network that allow audio and video information to be carried along with computer data. It is based on Local Area Network (LAN) technology.
- Robotics : It is a technology that enables an electro-mechanical system which can be programmed to perform manual tasks.

Software

Software brings life into the computer. It is instructions (or a program) required to run the computer. It guides the hardware how to do its job. The software which differentiates among the various kinds of jobs a computer can perform. Software consists of electronics instructions. A specific set of instructions that drives a computer to perform a specific task is called a Program. When a computer is using a particular program, it is said to be running or executing that program.

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Microsoft, WordPerfect, Ami pro for Windows are few of the Windows-based word-processors available in the market. Oracle, Ingres, Informix, Unify are some of the commercially available Rational Database Management Systems (RDBMS) packages. Auto CAD has been the most famous drafting package and it works on the Windows platform. Diagnostic are the programs used to diagnose the problems of your computers. These are very important programs and are able to rectify the problems of your computer to a certain extent by the programmer itself. Typical examples of such programs are Scan Disk, Smart Dog and Nortan Utilities etc. Coreldraw, PowerPoint and Persuaion are the Presentation Graphics or Business Graphic Packages which works in the Windows environment.

CHARACTERISTICS OF COMPUTER

Computer has become an essential part of our day-to-day activities. Presently they are being used in every sphere of life. Its growing importance, is because of its unique features.

- Accuracy as they do make mistakes but seldom because of their physical circuit. It they make mistakes, it might be because of the faulty programs.
- Speed as computer initially invented as a very high-speed calculator, helps in completing many scientific projects that were previously impossible. The landing on the moon would not have been possible if computer had not been there. When talking about speed of the computer, we don't talk in seconds or microseconds but in nanoseconds (10^{-9} seconds) or even picoseconds (10^{-12} seconds). A computer can perform about 3 million calculations per second.
- Versality the computers are capable of performing any type of task, as long as an activity can be put into logical steps from cooking in oven to a visit of an astronaut in space.
- Storage as computers can store massive amounts of information. This information can be used and reused time and again for years (unless something goes wrong with the hardware).
- Memory as any information stored in the computer's memory, it remains there till we delete it. Moreover the memory of computer is unlimited, we can store as much as we want.
- Automation as a computer keeps doing as task as programmed till it finishes, without any human intervention.
- Diligency because computer being a machine, does not show any signs of fatigue, tiredness, lack of concentration, or lost interest. The speed, accuracy and the quality remain absolutely same in the first and the last calculation.
- Above all qualities of the computer make them reliable and also make us too dependent on them. They can be run for years and years without any loss of data or any other problem.
- Reliability has been accorded to computers because of the above discussed characteristic along with high speed performance of a task.

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BASIC COMPONENTS OF COMPUTERS

A basic computer system consists of three primary components:

1. Memory : The memory provides a storage medium for the data and instructions to be executed. For the arithmetic and logical unit to operate efficiently, the stored information should be directly accessible at high speed. This access time is generally measured in terms of microseconds while the capacity is measured on terms of Kilo/ Mega bytes.

2. CPU : The Control unit together with the arithmetic logical unit (ALU) is known as the Central Processing Unit (CPU) or the brain of the computers. This is responsible for the execution of programs and synchronization of entire system. Since input, output and secondary storage devices are at the periphery of the CPU, these are called the peripheral devices or simply peripherals.

3. I/P and O/P Unit : The function of the I/P (input device) is to read and send data to the central processing unit of the computer. unidirectionaly, *i.e.*, from the input device to the CPU. The input device is analogous to human sense orgains.

The function of the output device is to report the data that has been processed in the CPU. The processed data again travels in one direction, this time from the CPU to the output device over cables (channels). The output device is analogus to human speech and other actions.

COMPUTER TERMINOLOGY

Bits, bytes, Kilobytes, megabytes:

Computer have a very elementary way to store data: they can remember only 0 or 1. A value of 0 or 1 is called bit and all computer data are stored as sequences of bits. A sequence of 8 bits is called a byte, which is a quantity large enough to store usually a letter or a digit (even though sometimes 2 bytes are necessary). Modern computers are able to deal with enormous quantity of bytes, forcing us to introduce other quantities:

- Kilobyte (KB), approximately 1,000 bytes,
- Megabyte (MB), approximately 1,000 KB or one million bytes,
- Gigabyte (GB), approximately 1,000 MB or one billion bytes,
- Terabyte (TB), approximately 1,000 GB or one trillion bytes.

Usually the text of a whole book can fit in some KB, while for an image in a good resolution (let's say ready to be printed on A4 paper) or for a modern song some MB are required, and a film in high quality needs some GB.

Computer box :

Computer as a rectangular box which is normally not opened unless required for repair contains the most promiment component called the processor, the brain of the computer. Here all the calculations and logical operations are carried on, and the whole computer is administered.

SYSTEM ARCHITECTURE

The computers architecture is mainly divided into three types of devices as

(a) Input Devices : The devices which gives instructions to the computer are called Input devices.

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Examples : Mouse, keyboard, Microphone, Scanner, CD-Drive, Joystick, Barcode Readers, Reel Camera, OCR, OMR, Webcam, MICR Device etc.,

(b) Output Devices : The devices which gives output data to users are output devices.

Examples : Monitor, Speakers, Printers, Plotters, Headphone and Projector etc.

(c) Processing Device : CPU is responsible for taking data inputted by the user and then performing any necessary processing as required.

(d) Peripheral Device : Devices that are connected to CPU Input peripherals are keyboards, scanner, webcams, microphones. Output peripherals are computer displays, printers, projectors, computer speakers.

INPUT DEVICES

(a) Mouse :

- It is a pointing device that working on principle of drag and drop icons detects two dimensional motion relative to a surface.
- To get properties of any object, we have to press Right button of mouse.
- The scroller is present between two buttons of mouse.

(b) Key Board :

- The most widely used device for Input. It is a typewriter- style device with keyboard having. characters engraved or printed on the keys and each press of a key typically corresponds to a single written symbol.
- Each press on key of key board is "keystroke"

IMPORTANT KEYS :

- Caps Lock : It is used to change the letter case of Text
- Function keys : F1 to F12 are 12 functional keys.
- Num Lock : It locks the Number pad and change the numbers into directional keys.
- Modifier keys : Alt, Ctrl, Shift
- Task manager keys : Alt + Ctrl+ Del. (Turn off user accounts)
- End : To bring cursor to the end of current line.
- Tab key : To indent (initialise) the paragraph
- Cursor key : Keys which move the cursor to different position on the screen. Ex. Page up, Page Down keys
- Toggle keys : Key which performs 2 different actions on Pressing such as Caps Lock, Num Lock

(c) Scanner : An electrical device that converts hard copy of text / image into a computer photographic image that can be stored in the computer memory.

Common scanner software Application Program Interfaces :

(i) SANE : Scanner Access Now Easy

(ii) TWAIN : Most common used scanners

(iii) ISIS : Image and Scanner Interface Specification

(iv) WIA : Windows Image Acquisition

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(d) Joystick : The device used in computer for playing games as a directional device.

(e) Barcode Readers :

Barcode : The lines of different length and width found on tags/ products and this code is recognized by computer system.

Barcode Reader : Through Input Automation, these readers take the rate/cost of product automatically at POS (point of sale) Systems.

(f) MICR Device : It is a device that can recognise human readable characters printed on documents such as cheques using a special magnetic ink.

MICR Code - Magnetic Ink character Recognition Code is a character recognition technology used mainly by banking industry to ease the processing and clearance of cheques and other documents.

- This technique used for cheque clearance in Banks.
- MICR Code is of 9 digits – 785 (City) 576 (Bank) 350 (Branch codes)
- First 3 digits indicates city code
- Middle 3 digits indicates Bank code
- Last 3 digits indicates Branch code

(g) OMR : Optical mark recognition

(h) OCR : Optical character recognition

OUTPUT DEVICES

(a) MONITOR : The device also called Visual Display Unit (VDU) mostly used for viewing output.

- Monitors clarity is based on its Resolution measured in Dpi (dots per inch)
- Each dot is called pixel.
- As the number of pixels increases, screen clarity is increased.

CRT : Cathode Ray Tube Screen,Low clarity

LCD : Liquid Crystal Display Screen, Medium clarity

LED : Light Emitting Diode screen, High clarity

(b) PRINTERS : Output device that produces the hard copy

Printers
- Impact Printers
- Non-impact Printers

(i) Impact Printers : This type of printer strikes paper and ribbon together to form character on paper.

– Graphics cannot be printed by using these printers.

- Daisy wheel : These are typewriters and slow printing used only for text.

  – Petals are typewriter keys

- Dot matrix : These are called pin printers.

  – These are bidirectional printers used in railway ticket printing.

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- Band Printer : Very fast, expensive and sound making.
  – Used in printing current Bills, Bus Tickets etc.,

(ii) Non-Impact Printers : Speed measured in characters per second
– These printers do not strike the paper but uses ink spray or toner powder.

- InkJet : Used for colour printing
  – These are replaced with Laser printers.
- Laser : – It prints more number of pages per minute, than other printers.
  – It prints high resolution on paper with quality graphics.
- Thermal Printer : It uses heat on chemically treated paper such as Fax machines .

(c) PLOTTER : It is a printer, accuracy measured in terms of repeatability and resolution.
– It is most widely used for large size colour printing (Graphics)
– It has penlike structures which prints graphics on flex according to computer instructions
Ex : Movie Banners Printing.

DEVICES ACTING AS BOTH INPUT AND OUTPUT DEVICES

Few devices that can function as both IP and OP such as.

(i) MODEM : It stands for Modulator and Demodulator. It modulates signals to encode digital information and demodulates signal to decode the transmitted information.
Modulator – Converts Binary Signal into Analog wave
Demodulator – Converts Analog wave into Binary signals.

(ii) FAX : It is also called Facsimile (telecopying or telefax). The original document is scanned with a fax machine (or a telecopier), which processes the contents as a single fixed graphic image, converting it into a bitmap, and then transmitting it through the telephone system in the form of audio frequency tones.

(iii) Touch Screen :
– The touch screen is used for both input and output.
Ex : Touch screen Mobiles, Touch screen Monitor.

(iv) Digital Camera :
– This camera takes / captures the image (input)
– Same image can later be seen on camera screen (output)

(v) AT-Head set : Advanced Technology Headset is used for talking and hearing the voice.
Ex: Mobile phone Headset

CENTRAL PROCESSING UNIT (CPU) :

It has various names as : • Processor, System unit • Computer tower or • Brain of computer

CPU Hardware :

- The CPU contains many hardware components that are together called as system unit.

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Hard ware and Software :

Hardware : The physical components of a Computer that we can see and touch.

Ex : CPU, Monitor, Keyboard, Hard disk, Floppy Disk, CD etc.

Software : It refers to the programs which are required to operate the computer, we cannot touch and see.

Ex. Windows-8, Android, DOS, Windows7, MS-Office, Operating System etc.,

CPU - HARDWARE COMPONENTS

(1) Motherboard : It is the most essential part of computer

- It contains RAM, ROM, Expansion slots, CMOS Battery, BIOS Chip, SMPS, FAN etc.,
- The communication between all these components is passed through BUSES,
- It holds together many crucial components of a computer, including CPU, memory and connectors for input and output devices.

COMPONENTS ON MOTHER BOARDS

(a) CMOS Battery :

- It stands for complimentary metal oxide semiconductor battery made of lithium metal.
- Its main functions are :
  - (i) To maintain RTC (Real Time Clock) in the computer system
  - (ii) To wake up the BIOS (Basic Input Output System) to perform the POST (Power on Self Test).

(b) BUSES : The communication lines between the components on the mother board are called buses. Their types are :

Address Bus :

- It unidirectionally carries only address from Hard disk to RAM.

Data Bus :

- It sends the data from RAM to Hard disk and receives data from Hard disk to RAM. Thus, it is bidirectional Bus.

(c) BIOS CHIP : (Basic Input Output System)

- It is the ROM chip on mother board that cann't be deleted.
- BIOS chip is hardware and it contains BIOS software files so it is called FIRMWARE.

(d) FAN :

- The cooling agent for mother board components.

(e) Expansion slots :

- These slots present on mother board are provided to install the extra cards such as video graphics cards and multimedia cards.

(f) SMPS : (Switch Mode Power Supply)

- It supplies power to CPU by converting AC to DC.

(g) PCI Slot : (Peripheral component interface slots) To connect external devices.

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(h) Processor Chip :

- Processor made of Silicon converts the input. These Computers are called as Silico Sapiens.
  Examples : Intel-core pentium series, i5 , i7 etc.,
- Speed of processor : 1 million 1 billion Hz per sec.

CISC
• Complex Instruction Set Computer • It allows more number of micro electronic signals • It uses complex addressing modes Ex. Pentium Pro, II, III
RISC
• Reduced Instruction set computer • It allows small and limited number of signals • It uses simple addressing modes Ex. IBM RS-6000, MC-88100

(i) Random Access Memory (Read and write memory) (RAM) :

- It is a volatic form of computer data storage.
- It can perform operations in Random.
- It is a hardware device in Rectangle shape.
- Its size varies from 256 MB to 8 GB.
- RAM is called system memory, Internal memory or simply memory.

TYPES OF RAM :

(i) SRAM (Static Random Access Memory) :

- It is the high speed RAM (It has 6 Transistors in it)
- It can continue to work / process with out refreshing the system

(ii) SDRAM (Synchronus Dynamic RAM) :

- To reduce the cost of SRAM, SDRAM was invented. With the same properties as SRAM only.

(iii) DRAM (Dynamic Random Access Memory) :

- It is low in speed of Access (It has 1 Transistor and 1 Capacitor)
- It requires times to refresh the system

Market Availability of RAM :

(i) SIMM (Single Inline Memory Module) :

- It has 30 or 72 pins
- It supports 16 and 32 bit data transfer Rates

(ii) DIMM (Dual Inline Memory Module) :

- It has 168 pins
- It supports 64 Bit data transfer Rate
  Ex. DDR 1, 2, 3 (DDR = Double Data Rate), DDR 3 is the fastest RAM

(2) Read Only Memory (ROM) : It is a class of storage medium used in computers and other electronic devices.

- It is non volatile memory and permanent memory.
- It cannot be erased. It is read only memory but not writing on it.

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TYPES of ROM :

(i) PROM : Programmable ROM (It is Empty chip to add any program to it)

(ii) EPROM : Erasable Programmable ROM

(iii) EEPROM : Electrically Erasable Programmable ROM

(iv) Flash EEPROM memory : It works faster than EEPROMs because it erase a block or the entire chip and then rewrites it.

PORTS :

MIDI PORT : Musical Instruments digital input

- These ports present on CPU front or back side are used to connect speakers, MIC, Head Sets.

Parallel Port :

- These ports present on backside of the CPU are used to connect printers and scanners.

USB Port : Universal Serial Bus.

- This port is to connect all external devices with the cable
- Now pen drives and data cables are connected to this port only.

Hard Disk :

- It is the storage point of computer.
- It stores operating system, softwares and Data etc.
- Memory varies from GB's to TB's in size for Hard disk capacity.

TYPES OF MEMORY AND DEVICES

(i) Primary Memory :

- It is system's main memory called RAM.
- This is used only for processing data not for storing the data.
- Can be temporary and volatile memory or Internal memory.

(ii) Cache memory :

- The fastest memory in computer and it is volatile.
- It holds the previous instructions of computer.

(iii) Secondary memory :

- The memory which is stored for further or future use is secondary memory.
- The memory is non-volatile but it can be mainpulated.
- These, also called Auxillary memory or External memory.
- Examples of secondary storage devices , CD'S , floppy disks, DVD'S, memory cards, Flash cards and magnetic Tapes.

Secondary Storage Devices

- Optical Storage
- Magnetic Device
- Solid State Storage Device

These storage devices mainly differ in the following aspects :

- Technology used to store data.
- Capacity and size of data, they can hold.

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- Portability of storage device
- Access time to store data

Floppy Disk :

- It is a magnetic storage component in form of 8 inch disks
- The memory size of 3.5 inch floppy disk is 1.44 MB
- The memory deleted from floppy disk cannot be retained back from computer.
- These consist of Mylar plastic disk coated with metal oxide that rotates within a hard plastic casing. The oxide layer stores the data.
- Examples : Super disks, HIFD (High Capacity Floppy) Disk.

CD : Compact Disc.

- Invented by James Russel in 1965 has memory capacity of 700 MB
- It is written or read by laser beam of light
- Three basic types of CDs : CD-ROM, CD-R and CD-RW
  - (i) CD-ROM (Compact disk read only memory) : They are used for selling movies, music etc.
  - (ii) CD-R (Compact disk-Recordable) : It can be written only once. It can be read many times (WORM). These are used for creating backup, etc.
  - (iii) CD-RW (CD-Rewritable) : Also known as erasable disks. are used to save or delete data several times.

DVD : Digital versatile disc with memory size of 7 GB

Bluray Disc : These used store high definition quality videos only.

- 25 GB and 50 GB memory disks are called Bluray discs.

Magnetic Tapes :

- These are magnetic storage medium components. These follow sequential access medium principle.
- Every time we have to read data from beginning Part only, no skipping. Ex: Cinema Reels, cassette player, video recorder, video camcorders.

Solid state storage devices :

These devices have got no moving parts and data is stored and retrieved from them in similar manner as it would be from computer memory. Ex : USB disk, Pen drives, etc.

Disk formating :

Formation of Tracks and sectors on any disk is called Disk formating on which clusters hold the data.

- UDF : Universal Disk Format (FAT / NTFS)

Flash devices / Flash memory :

- The devices with non-volatile memory like digital camera, ipods are connected through cables to access their memory in computers.
- Memory accessed through cables is called flash memory.

Virtual memory : Whenever the RAM memory insufficient to hold the processing data, it uses hard disk memory as hidden memory to process the specific task. So, the memory utilised from hard disk is called virtual memory.

Example : When installing operating system (8.2 GB), if the RAM is 4GB size, it uses virtual memory.

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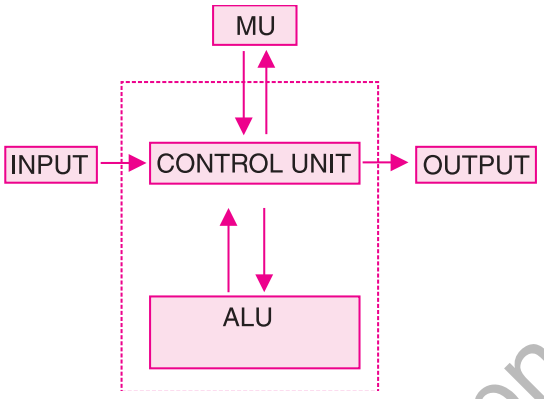
Memory Cards : SD that stands for secure digital memory cards (SDMC, SDHC) and used in digital cameras and mobile phones.

CPU Processing units :



CPU mainly divides its processing into ALU, CU and MU

(i) ALU : Arithmetic and Logic Unit that performs all the arithmetic and Logical processing of CPU.

Accumulator : It holds the processing data and output result to display.

Program counter : It holds the next instruction that has to be performed by ALU or Registers.

Memory Data or Memory Buffer Register (MDR or MBR) :

- It holds the complete data on the hard disk while Processing.
- It acts like a buffer and holds anything that is copied from the memory ready for the purpose to use it.

(ii) CU : Control Unit

- The Control unit controls and coordinates all the parts of computers (system components) using control pins.

(iii) MU : Memory Unit contains RAM, ROM and Hard Disk

LANGUAGES AND SPECIFICATION

FORTRAN : Formula Translation (1957) used for Scientific Research / Calculations

COBOL : Common Business Oriented Language (1957). Used in business computations

ALGOL : Algorithmic Language that laid formulation for developing the C, C++ and Java languages

C :

- Invented by Dennis MacAlistair Ritchie in 1972 is now replaced by Java.
- Printf takes the output statements in code.
- Scanf takes input data in code.

C++ :

- The computer games (Basic) were developed using this language, invented by Bjarne Stroustrup (1983)

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HTML : Hyper Text Markup Language.

- The web pages are saved or viewed in HTML format only.

JAVA : Applets can be created by this language.

- The language used for webpage creation, websites hosting.
- Developed by sun micro systems, invented by James Gosling and his Team.

XML : Extended Markup Language (world wide web consortium)

PHP : Personal Home Page. (Designed by Rasmus Lerdorf -1995)

SQL : Structured Query Language, used for database tables creation

ASP.NET :

- The language came in recent days for programming (web designing)

Note : The computers cannot understand any of the above languages, it needs only machine language or Binary code to understand which means 0's and 1's

Programming Language Translators :

- Computer can understand only binary code / machine code
- So, when we write our program in Java, C and C++ or Assembly language, it needs to be converted into Binary code.

Translator : The translator converts the given code in to machine code or binary code.

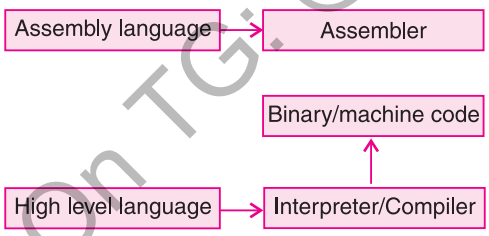

Figure : Translators of Languages

(i) Assembler :

- It converts the Assembly Language code into machine code.

(ii) Interpreter :

- It Compiles the program code line by line and checks for errors. Hence, is time consuming.

(iii) Compiler :

- It compiles the entire program code in a single time for errors.
- It is a time saving translator.
- It cannot execute the programs but converts source code into object code.

Terms Related to Programming Language :

(i) Instruction : Any single text given to computer is called instruction. Ex. 0 or 1

(ii) Program : The combination of 'n' number of instructions is called a program and specific set of programs are also called softwares.

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(iii) Algorithm : The step by step instructions of a program written in sequential order is called algorithm.

(iv) Flow chart : The graphical (pictorial) representation of the pseudocode or algorithm are called flowchart.

Symbols used in flowchart

↑ Flow Direction (Arrow mark)

⬭ Start / stop (Ellipse)

▱ Input / output (parallelogram)

▭ Processing data (Rectangle)

◇ Decission making (Rhombus)

○ Connector to next page (Circle)

Different types of Languages :

(i) Low level Languages : Machine understandable languages Ex. Assembly Language, COBOL, PASCAL, BASIC.

(ii) High level Languages : Human understandable languages Ex. C++, Java, SQL, VB.

- Assembly Languages uses MNEMONICS as code in symbols.
- C language is a combination of two with High level Language and some features of low level language.

Important terms

- Control structures : The Conditions and Loops written in source code.
- Reserved Words : The words that are kept aside for its use by programming language.
- Bug : It is also called error (mistake in program code) or Glitch.
- Testing : Finding errors in the software.
- Debugging : The process of correcting the errors in the software code.
- Platform : The combination of operating system and processor is called platform.

  Example : Apple macintosh and PC'S are 2 different platforms
- Patch : The vendor - created programs that are available through Internet to repair software.
- API'S : Application program Interfaces is a set of routines, protocols and tools for building software applications. API makes it easier to develop a program by providing all the building blocks.
- Executing : The process of carrying out commands.

Types of Errors

(i) Logical errors :

- The fault in the logic of program code causes to get wrong outputs / results.
- In this case the program is executed to get result

  Ex. Correct logic $z = x + y$;

  Mistake logic $x = z + x$;
- One gets output for x in place of z due to logical error

(ii) Syntax Errors :

- The fault / mistake in the syntax (structure) of the program code causes failure to execute it.

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- In this case program is not executed.

  Ex. Missing of semicolons in the code

  Correct syntax $z = x + y$;

  Mistake syntax $x = z + y$
- One will not get output
- A functional Language reflects the way people think in mathematical way.
- A programming Language consists of set of Rules *and* Syntax and structure. It is the Intermediate between human language and machine language.

LOGIC GATES : These are the basic building blocks of IC'S.

- We have 3 basic Logic gates mainly as and, OR and NOT.

AND All input must be in '1', to produce '1' as output

OR Any one input or more is '1' to produce '1' as output

NOT It also called inverter has only one input and one output
If input is '1', the output is '0', vice versa

NOR Any one input or more is '1' to produce '0' as output

NAND All input must be in '1', to produce '0' as output

XOR If any one input is '1' , but not if 2 or more input are '1', the output is '1'

Memory Measurement : Memory in computer is measured in Bits

Bit	Binary digit (either 0 or 1)			
4 Bits	Nibble			
8 Bits	1 Byte			
1 Kilobyte		1024 bytes	10^3	2^{10} Bytes
Megabyte	1024 KB	1 million Bytes	10^6	2^{20} Bytes
Gigabyte	1024 MB	1 Billion Bytes	10^9	2^{30} Bytes
Terabyte	1024 GB1	Trillion Bytes	10^{12}	2^{40} Bytes
Peta Byte	1024 TB10^{15}	2^{50} Bytes		1 Quadrillion Bytes

- Exabyte, Zettabyte, Yottabyte are the next higher measurement

1 Byte — 1 character (ASCII)
— 256 numeric (0 to 255)

Note : "Always 'B' represent Byte, 'b' represents bit.

Booting : The process of loading operating system from disk to RAM is called Booting.

- Without booting, computer cannot perform any task.

(i) Warm booting : The process of restarting/ turning on the computer, which is under on / working position.

(ii) Cool Booting : The process of starting / turning on the system which is under off position.

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SOFTWARES

SOFTWARE (S/W) : The set of programs written by programmers to perform some specific tasks is called software. Software is a set of programs.

Types of Softwares

- System software
  - Operating system
- Application software
  - Spread sheet
  - Word processors
  - Graphics presentation
  - Database management
- Utility software
  - Disk Backup
  - Disk Restore
  - Disk Checkup
  - Disk Format
  - Antivirus

1. System Software : The software which performs various types of functions in order to manage and organise files of computer. It is mandatory software to run a computer.
   - It provides a platform for running application software.
   - It can be divided into two different categories:

   Operating system is the system software and supervisor of computer functions. It creates interface between user and computer. Examples of operating system :

   (i) Z/OS : It is a 64-bit Operating system for mainframe computers produced by IBM. It can directly communicate via TCP/IP (IPv6).

   (ii) Windows Operating System : Introduced in 1985 by microsoft corporation. It supports GUI (Graphical User interface) mode. supports multi tasking. Windows 95, 98, ME, XP, 7, Server, 8, vista are few examples

   (iii) LINUX Operating System : It is a free multi-user operating system. It supports multiprogramming (time sharing).

   (iv) MS-DOS : DOS stands for single user command driven disk operating system. Directories are storage files.

   - Directory within (Root) Directory is sub directory

   Ex. Main (D Drive) → Songs
   ↓ ↓
   Root Directory Sub Directory

   Examples for few DOS Flies :

   . exe - Executable file . com - Command files
   . Bat - Batch Files. . Prg - Program files
   . Sys - System files

   (v) UNIX : It is a family of multitasking, multiuser computer operating systems.

   (vi) Solaries : It is an Unix operating system developed by Sun Microsystems. It is known for its scalability.

   (vii) Ubuntu : It is a Debian based Linux operating.

   (viii) Apple macintosh : This operating system is only for Apple Products.

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(ix) Mobile Phone o/s : Ex. Bada, Symbion, Android, Windows 8, IOS (Inter Networking Operating System for Apple Phones). Smartphones uses this operating system for Google Applications.

Classification of operating System :

(i) Multi-User o/s : It allows 2 or more users to run the programs at the same time. Ex. UNIX / LINUX

(ii) Multi Tasking o/s : It allows more than one program to run concurrently. Ex: UNIX, WINDOWS

Such as working on computer and Listen to Songs at a time.

(iii) Multi Processing : It supports running a program on more than one CPU or processor.

(iv) Multi threading : It supports different parts of a single program to run concurrently on system.

2. Application Software : These are the end - user programs that do real-work for users. It cannot run without system software.These are created for user convenience only.

Examples :

Word Processor s/w	MS Word, words star, softword, word perfect
Graphics Presentation s/w	MS Power point, Corel Idraw, Flash
Spread sheet s/w	MS Excel.
Database Management s/w	MS Access.

- System software and Application software are two basic types of softwares.

Syntax : Set of Rules in programming Language

FAT : File Allocation Table

NTFS : New Techonology File system

3. Utility Softwares : These are the softwares that maintain and check for health of computer by scanning and managing data. These softwares performs a single and specific task.

Examples :

(i) Disk Backup s/w	Creates backup of system files and data
(ii) Disk Restore s/w	Restores the backup files to system from backup image
(iii) Disk checkup s/w	Checks the data of disk
(iv) disk format s/w	Forms of tracks and sectors on disk
(v) Antivirus s/w	Detects and deletes the virus in system

4. Firmware : The hardware chip that is having storage of software is called firmware.

Ex. BIOS operating system is stored on BIOS chip.

5. Embedded Software : The software that is used for specific devices such as car, TV, Washing Machine and Watch etc. is called Embedded Software .

Device Drivers : The special and specific programs written to perform task by specific devices only.

Example : Printer drivers, Webcam drivers, Scanner drivers.

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- Windows ME : In this, ME stands for Millenium Edition
- Crash : When your computer stops working suddenly without any instruction, this is called crash.
- Backup : It creates a restore point for all the system files and data. It creates a separate copy of system data base.

Note : IBM introduced personal computer in 1981.

Keyboards and languages

Before starting this section it is necessary to take a close look at your keyboard. Locate these keys since they will be used in the rest of this manual and are very useful in many programs:

English Keyboard	Main Function
CTRL	Control
ALT	Alter
ALTGR	Produce character on the key's right left
F1to F12	Functional Key's
DEL	Delete next character
INS	Toggle insert/overwrite mode
Home or ↖	Go to beginning
END	Go to end
PG ↑ and PG ↓	Go one page up or down
BACK SPACE or	Delete last character
ENTER or ↵	Enter data
TAB or ⇄	Move through the window
SHIFT or ⬆	Capitalise letters
CAPS LOCK or ⬇	Keep SHIFT pressed
ARROWS ←↑→↓	Move the cursor

Regional and language settings :

With a multilanguage Windows installation, keyboard setting or menus' languages may be changed clicking on the Start icon, choosing "Control panel", then "Clock, Language and Region", then "Change Display Language", and modifying the appropriate setting.

Desktop and application bar :

The first thing commonly seen after typing the log in name and password if required is the user's Desktop, different for every user, if the computer asks for log in name. It contains, usually on the bottom, the application bar with the start menu on the left. When clicking the left mouse key on this menu a long list of things appears; the most interesting ones are:

- Programs, with the complete list of programs installed on this computer.

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- Disconnect icons from which the user can disconnect from the computer or turn it off.
- Computer, from which the user can access the computer's hard disks.
- Network, from that the user can access the network connected to the computer.
- Control panel, which contains the operating system configuration and should not be accessed unless the user perfectly knows what he is going to do.
- User's home and Documents, which contains all the user's files.

Next to the start menu's icon there are the quick launch icons, small images which start, when clicked on, the most common programs. At the center of the application bar there are the currently running programs and on the extreme right other running programs, usually those controlled by the operating system. The technical programs which are not considered interesting tE the user (including viruses!) are nEt displayed En the applicatiEn bar. The current keybEard language and the clEck are alsE displayed in the applicatiEn bar: tE change their setting Ene simply needs tE dEuble click the mEuse left key.

Computer locking problem :

MicrEsEft WindEws sEmetimes becEmes unstable and typically when it is dEing sEmething very impErtant and urgent, lEck and refuse tE respEnd tE user's actiEns. When this happens, it is usually caused by the prEgram that was used and therefEre the first thing tE dE is tE try tE clEse the current prEgram. If this dEes nEt imprEve the situatiEn, the Enly Ether sElutiEn left is tE turn Eff the cEmputer. The list Ef EperatiEns tE try until the cEmputer answers tE user's cEmmands is :

1. if the mEuse wErks, click the X buttEn En the prEgram windEw Er Etherwise press ALT+F4;
2. press CTRL+SHIFT+ESC; select the prEgram frEm the list and press End prEgram;
3. press CTRL+ALT+DEL and, frEm the bEttEm right icEn, chEEse Shut DEwn;
4. press the cEmputer En/Eff buttEn;
5. unplug the electric pEwer.

In any case all the current unsaved wErk will be lEst; in the last twE cases the Eperating system can sEmetimes be damaged but very Eften it will repair by itself the next time the cEmputer is turned En. TherefEre, it is always a very gEEd idea tE save very Eften the current wErk, especially when it is impErtant Er difficult tE redE.

DESKTOP

File system

Before starting this section it is necessary to :

1. Epen the CEntrEl Panel frEm the start menu icEn
2. chEEse Appearance and PersEnalisatiEn
3. chEEse FElder OptiEns
4. chEEse View
5. deselect "Hide extensions for known file types".

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Files and directories :

Software is stored on storage devices in a special container called file. The operating system uses a lot of files represented by incon for itself and for its data. A program usually uses one file for itself and other files for its data.

Another special object is the directory or folder. It is basically a container for files and other directories and is represented with an icon depicting a yellow closed or open folder. Double clicking on a directory opens a new window which presents the directory content.

Each storage device is a big directory, accessible from My Computer window, which contains directories and files. Each of these subdirectiories may contain other files and other subdirectories, and so on in a hierarchical way, forming a tree with the hard disk (or another storage device) as the root, directories as branches and files as leaves. On UNIBZ computers, the usual hard disk are "C" which contains programs, "E". that further contains courses information and "F". Which contains user's reserved space. Disks directories "A:". and "B:" are usually reserved for floppy disks, and "D:" or "Z" for CD-reader.

Choosing the Views menu of a directory windows will provide the user with five different ways to look at files and directories, the most important way being the Details which can show interesting information on files and directories.

Each file and directory can be univocally identified by its absolute path or address. For directories it is the path which appears on the address bar of the directory window, while for files it is the path of their containing directory followed by "\" and the file name, e.g. "D:\Program Files\HP\Common" is the address bar. While, the HPeDiag.dll file has the absolute path "D:\Program Files\HP\Common\HPeDiag.d||".

Note that, for Windows operating system, capital or small caps letters in paths are perfectly equal.

A special and tricky object is the link or shortcut. A link is simply an address to a file or directory, it is not a real file or directory. When the user clicks on the link, the computer behaves exactly as if the user is clicking on the real file or directory. However, any copy/move operation on the link will simply copy/move the link and not the real file or directory; especially copying/moving the link to another disk will probably cause it to malfunction. Therefore, it is a good idea for novice users to avoid using links at all.

Files' operations :

When double clicking on a file, Windows usually starts a program. The user is totally unaware of an important difference:

- double clicking on a program runs the program which was double clicked
- double clicking on a file calls the program associated with that file and runs it, at the same time telling the program to open the file. If no program is associated with that file type, Windows asks the user which program should open the file.

Copying a file means reproducing it to another location or to the same location with a different name. To copy a file or directory windows offers several methods, the most commonly used being.

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- drag the object to the destination. If a plus symbol does not appear, press CTRL key to have it appear while dragging. Release the object at the desired/ selected destination;
- select the object and click the right mouse button. Select "copy". Point the mouse to the destination and click the right mouse button. Select "paste".
- select the object and press CTRL+C. Point the mouse to the destination and press CTRL+V. (Paste).

Moving a file means moving it to another location. Moving a directory means moving it to another location together with its entire tree of subdirectories and files. To move a file or directory windows offers several methods, the most commonly used being:

- drag the object to the destination. If a plus or a link symbol does appear, press CTRL or SHIFT key to remove it. Release the object in the destination;
- select the object and click the right mouse button. Select "cut" and the icon becomes lighter. Point the mouse to the destination and click the right mouse button. Select "paste".
- select the object and press CTRL+X and the icon becomes lighter. Point the mouse to the destination and press CTRL+V.

To create a link to a file or directory:

- drag the object to the destination of the link. If a link symbol does not appear, press CTRL+SHIFT until it appears. Release the object in the destination;
- select the object and click the right mouse button. Select "create shortcut". A link is created in the same directory.

Deleting a file means often putting it into the trash from where it can be recuperated unless the trash can is emptied. Deleting a directory mean putting it to the trash can together with its entire tree of subdirectories and files.

To rename a file or directory, simply select the object, click on the name and retype it. Usually Windows accepts every name, but novice users should stick with letters and numbers and spaces, since other characters may be forbidden.

To create a new directory, simply right click the mouse and choose "New" and "Folder". After the creation, name it.

Sometimes files occupy a lot of space and need to be reduced to save disk space or to be sent by e-mail; other times files must be put in a package to remain together or to be sent as a single file via e-mail. These two operations are accomplished compressing a set of files and directories, which means using a special program (WinZip or IZArc or Power Archiver or the operative system itself) to reduce (from 0% to 90% depending on the file type) the file size and produce a new single file called zip-archive containing all the selected files and directories.

To compress a set of files and directories:

1. select the files and directories all together,
2. click the right mouse key,

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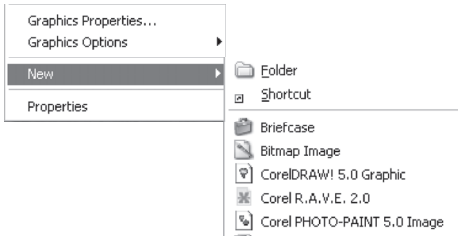
3. select "Send to" → "Compressed (zipped) Folder" or choose your compression program and select something like "Add to archive...",
4. a dialog box may appear asking you to choose the zip-archive name and its destination.



5. to make it quicker, the compression program suggests a possible zip-archive name directly at step 3: the user can select it and rename or move it later.

Other files or directories may be added later to the zip-archive simply by dragging them on the zip-archive file (this is a copy and not a move operation).

To extract files from a zip-archive file, simply click the right mouse key on the file and from the drop-down menu choose the appropriate extract option: the content will appear in the chosen location together with all its directories' structure.

File types :

Windows identifies a file type by its extension, which is everything after the last dot in the filename. Usually it is a 3 or 4 character acronym. Using the file extension, Windows knows the file type and decides which program will open that file. If the file extension does not show up, follow the instructions below given in the table. The most important file types are :

File type	Typical programs that openit	Typical extensions
Program	itself	.exe .com. bat
Compressed	WinZip/IZArc / Power Archiver	.zip
Text	Notepad	.txt.csv
Document	Word/Acrobat/Powerpoint	.docx .doc. rtf .pdf .ppt
Sheet	Excel	.xlsx .xls .csv
Image	Explorer/Picture Fax Viewer/ Paint/Office Picture Manager	.jpg .jpeg .gif .bmp
Video	Media Player	.avi .mov .mpg .mpeg
Audio	Media Player/Win Amp	.mp3 .wav
Web page	Explorer	.html .htm

File sharing :

On the same computer different programs can try to access the same file at the same time, or on network different users can try to do it. When this happens, Windows locks the file as soon as a program, able to write on it, opens it. Other programs trying to open it will be allowed to open it in read-only mode: they may be read, but are not allowed to be modified

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nor users are allowed to move or delete it but simply to copy it. As soon as the locking program closes the file, Windows releases the lock and another program may take it.

Another way to forbid use of files is through permissions. Click the right button of the mouse on a file or directory and select "Proprieties" and "Security". The security dialog box shows the list of users or groups of users who may access this object, while not listed users may not access it. For each user or group this dialog box displays the list of permissions.

The owner of the file usually has full control on it and may change permissions or add new authorized groups or users. A special group is the Administrators group with a full control on every object.

COMPUTER NETWORKING

Network : The group of computers connected together either physically or in wireless medium to share the files and Information, software, hardware (CPU) through network such as Internet.

Node : Every computer in network is called Node. Both clients and servers are said to be Nodes.

Computer network :

A computer network is a set of devices which communicate and share resources.

Resources sharing :

Resources sharing is what makes computer networks different from a general networks and this is often over looked by the novice user. Resources which can be shared are:

- the processor or the memory
- hard disks
- CD-reader or DVD-reader
- programs
- connection

Server and client :

A computer network interaction is based on the client server architecture. When considering a single interaction, one computer is the server and the other one is the client. The server offers its resource, usually programmed to wait until someone asks for its resource. The client is the computer which uses the resource.

The same computer may be the client for a service and the server for another service. For example, a library computer may have a CD inside its reader shared to the network (server for the CD) and may be at the same time used by a user to print his own documents (client for the printer).

TYPES OF NETWORK

1. PAN (Personal Area Network) : In the sharing of files / information between two computers by connecting them with cable / bluetooth / infrared Rays. By using PAN, we can also share internet connection typically within a range of 10 metres.
2. LAN (Local Area Network) : The small and single site network which connects the computers in a building and also to adjacent building.

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HUB is the connecting device used in connecting computers in the LAN

Example : Internet cafes, college Labs, college hostel etc.

3. MAN (Metropolitan Area Network) : The network that connects between different metropolitan areas (Ex : India to U.S.) Cable TV is the best example

   Satellite signals also used in MAN.

4. WAN (Wide Area Network) : This is the network geographically dispersed collection of LAN'S

   To connect WAN, It uses X.25 protocol technology that widens the signal strength. Ex: Internet, www (world wide web)

Types of LAN or Topologies :

Topology : The way of computers arrangement in connecting the LAN or Network is called Topology.

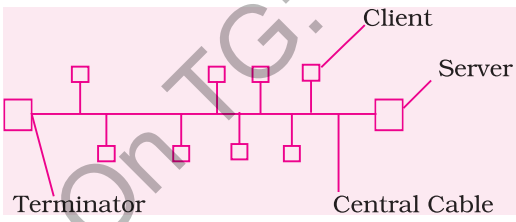
We have generally 6 topologies :

(i) Bus Topology (ii) Ring Topology
(iii) Star Topology (iv) Mesh Topology
(v) Tree Topology (vi) Hybrid Topology

(i) BUS Topology :

The computers are arranged in such a way that Bus seats are arranged in general life Bus.

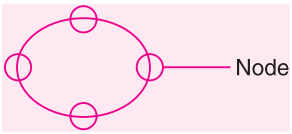
- Easy to connect a computer or peripheral to a linear bus.
- Requires less cable length than a star topology.



The central cable in this topology is called Back bone of Network

If the Backbone fails, the entire network fails.

(ii) Ring Topology :



In Ring LAN, all the nodes are connected in a circular path.

Here, there is no central server in the network. In this network, every device has exactly two neighbours for communication purposes. A failure in any cable or device breaks the loop and takes down the entire network.

- To implement this network, one typically uses FDDI, SONET, or Token Ring Technology.

To avoid collisions in data transmission, the tokens are provided to all the nodes. When the token time comes to a specific node, it can transmit

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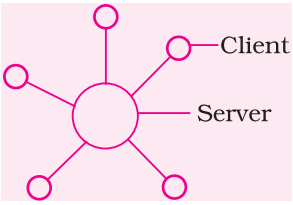
data to remaining systems / nodes. Failure in a single node causes entire network failure. It has n nodes and n connections in number.

Example : Found in office buildings or school campuses.

(iii) Star Topology: Many home networks uses the star topology. A star network features a central connection point called a 'hub' that may be a hub, switch or router.

- It is low cost easy to install and wire.
- Easy to detect faults and to remove parts.



The central Server sends data and receives data to / from all the clients. If one node fails, entire network does not fails. If central server fails, entire network will fail. Very easy for fault diagnosis.

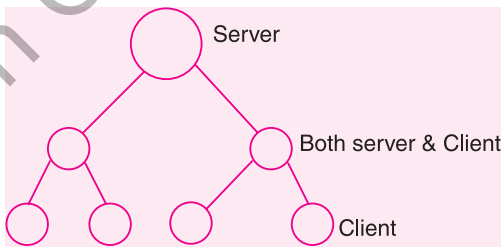
Star topology is the best topology to connect in Real life with n nodes and n-1 connections.

(iv) Mesh Topology :

Very high cost in construction of mesh Topology. Each node have connection with all the remaining nodes. Very difficult for fault diagnosis. Messages may use several possible paths from source to destination.

Fault Diagnosis: Finding the disconnected wire or node in the network is called fault diagnosis.

(v) Tree Topology : It integrate multiple star topologies together onto a bus. It is supported by several hardware and software vendor. Point-to-Point wiring for individual segments is done.



The computers are connected from one to another

The possibility for a node to act both as client and server is only in tree topology.

(vi) Hybird Topology : The connection of nodes with the combination of any of the two topologies is called as Hybrid Topology. e.g. Bus topology + star topology or star topology + Ring topology

Docking station : The station to which the laptops are connected to make them for converting as projectors or big screens like desktop and LCD' Screens.

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TYPES OF WAN'S :

(i) PSTN (Public Switched Telephone Networks) :

Designed for telephone, which requires modem connection

It is used in FAX machine.

It is analog low speed transmission.

(ii) PSDN (Public Service Digital Network) :

This network connects public with private networks through e-mail services and chating.

It is high Reliable and quality communication.

(iii) VAN (Value Added Network) :

It provides Electronic Data Interchange (EDI). in which the owner rentout network for subscribers.

Ex: Invoice and sale purchase order.

(iv) ISDN (Integrated Services Digital Network) : It is meant for limited distance only.

It uses both modems and multiplexers

Network Architecture : The construction of nodes (Computers) to form as network structure is called network Architecture. It can be

- Virtual Private Network (VPN) is a way to recognise a computer outside the LAN as a trusted computer : the user is identified with a password and his computer, even though connected via Internet, will be considered as part of the LAN, for as long as it remains connected. VPN is typically required to identify portable computers connected via wireless connection.

Network Components

Star topology : Computers and devices can be connected in different ways. The must typical topology is the star network : computers are divided into groups and are connected directly to a special device called hub (other similar devices called switch and router can do the same work). Every hub is connected to a main hub; in very large companies there are many main hub connected to a higher level hub, and so on.

Cables : The network connecting components are the cables, which often determine the speed of the LAN. Cables have a speed measure in bps (bits per second) which indicates how many bits can flow through the cable in one second.

- Ethernet cables have a speed of 10 Mbps and can thus carry 1.25 MB each second, meaning that, for example, a 600 MB movie can be transferred in 8 minutes from one computer to another one, supposing no one (neither users nor computers) is using that network tract for other purposes during the transfer.
- Fast Ethernet cables have a speed of 100 Mbps.
- Giga Ethernet cables have a speed of 1 Gbps.
- A wireless network, a cableless network where computers use radio signals to communicate, has usually a theoretical speed of 100 Mbps but its practical speed, which can change a lot due to environment condition, is around 10 Mbps.

To find out how much time does it take to transfer a file with a size expressed in bytes, divide the connection speed in bps by 8 to find out the

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byte rate per second and then divide the file size by the speed to find out the number of seconds it takes for the file transfer. For example, to transfer a 600 MB file through an Ethernet connection, find out the speed of 1.25 MB per second (1,250,000 bytes per second) and then divide 600 MB (or 600,000,000 bytes) by 1.25 (or by 1,250,000) to find out the time of 480 seconds, which is 8 minutes.

Gateway : When a LAN is connected to the Internet, there is one, or sometimes more than one, special computer called gateway. It is the only computer physically connected to the Internet and on it several administrative and security programs run. The main ones are :

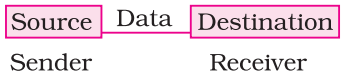
- Firewall : A program in charge of rejecting unwanted incoming connection attempts (which can attack the internal security) and sometimes of forbidding unauthorised outgoing connections (which can be users trying to perform operations the network owner does not want).
- Domain Name Server (DNS) : A program in charge of dealing with computer addresses.
- Webserver : A program in charge of publishing web pages. The webserver offers the local web pages to users outside, answering to requests coming from external users;
- Mailserver : in charge of receiving e-mails from the Internet and dispatching them to the right local user (according to the name before the @ and of receiving e-mails from the local users and dispatching them to the right external mailserver (according to the domain name after the @).

These programs usually all run on the gateway for large companies' networks, while for smaller networks, such as the ones of small office or home environments, DNS, mailserver and webserver run on the Internet Provider computers (implying that the local network depends on external resources for e-mails, its own web pages and domain names) and the firewall usually runs on every computers.

TYPES OF DATA TRANSMISISON :

- Data Transmission is the process of communication of 'data between source (Sender) and destination (Receiver)

(i) Simplex Transmission :

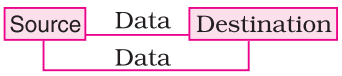


In this type, the communication is processed only in one direction from sender to Receiver.

Reciever cannot respond to the sender.

Example : Radio channels ; TV channels

(ii) Half Duplex Transmission :



The communication between source and destination is bidirectional in this type. However, the communication is possible one after another not simultaneously.

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Ex: Walky Talky, FAX machine.

(iii) Full Duplex Transmission :

The communication of signals between source (sender) and receiver (destination) at a time.

They need not wait for one another to send request or response

Sender — Data — Receiver

Ex. Telephones, Chating, messages etc.

Different elements used for Data Transmission :

(i) Coaxial Cables : The cable TV's are connected through these cables.

(ii) Optical Fibres : These are very reliable, rest free and very high speed data transfer.

(iii) Wireless Medium : Using different ways of wireless medium, allows data transmission to takes place.

INTERNET

Terms Relating Internet :

Intranet : The network of systems with in an organisation and not able to be accessed by the outside organizations.

Ex: Campus and Corporate networks, Database in CID (Crime Investigation Department)

Extranet : The organization given permission to outside another organization to access their data, this is possible through extranet.

Ex : A campus extranet would allow parents of the college student to log in and pay tution fee and look at other information.

Protocol : The set of governing rules on network are called protocols.

TelNet : It is a protocol that allows the system to connect remote computer for accessing data and internet.

Ex : If A and B are two systems having Telnet protocol, only A is having Internet facility than through Telnet, B can use the same.

Evolution of Interent :

ARPANET : The first intranet /Internet developed in 1969 by US Defence for the internal communication.

- Full form is Advanced Research Projects Agency Network. Vinton cerf is the father of Internet

OSI (Open Systems Interconnection) MODEL

It stands for open systems Inter connection Model

It has divided model into 7 Layers

The communication from sender to receiver and Viceversa happens in network through this OSI reference model only.

The 7 Layers of OSI model are :

(1) Application Layer (2) Presentation Layer
(3) Session Layer (4) Transport Layer
(5) Network Layer (6) Data link Layer
(7) Physical Layer

- The physical layer is the first Layer in OSI model
- Application Layer is the seventh (last) layer in OSI model.

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Layers 1 to 4 deals with end to end communication between data source and destination.

Layers 5 to 7 deals with communications between network devices such as Routes, Switch, bridge etc.

OSI Reference Model Table

No.	Layer	Application	Protocols	Devices
1.	Application Layer	Input and out put of Data	HTTP, SMTP, SNMP, FTP, User Interface Layer	Gateway POP, DNS
2.	Presentation Layer	Coding and Decoding Compression and De Compression Encryption and Decryption	-NO-	Gateway
3.	Session	Maintains User Layer Sessions Host Communication	-NO-	Gateway
4.	Transport	Provides Acknowledgement	TCP, UDP	Gateway
5.	Network Layer	Packets Formation Network Connection	IP, ICMP, ARP	Router
6.	Data Link Layer	Frames Formation Error Detection and Correction	NOt Required	SwitchBridge
7.	Physical Layer	Data Converted in to electrical, electromechanical and Digital Signals	NOt Required	Repeater

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TCP /IP Model

TCP / IP is the internet connecting protocol suit with only 4 layers. The presentation layer and session layer are absent in TCP / IP Model. Data link layer and network layer are taken as single part in TCP/ IP Mode.

ISP : Internet service Provider

It provides the Internet facility through world wide web.

It is the authority to permit client / individual for connecting to Internet

IP Address : Internet Protocol Address is unique address provided by ISP to the single/ Individual system on the network.

Internet Protocol Versions :

(i) IPV6 Internet Protocol Version 6. It supports 128 Bit address length for future use

(ii) IPV4 Internet Protocol Version 4. It supports 32 bit address length for current generation use.

ADDRESSES

IP numbers : Computer networks use the Internet Protocol (IP) address system: every network device is identified by an IP number composed of four numbers from 0 to 255 separated by dots. For example, 15.0.234.65 or 255.54.9.23 are valid IP numbers.

Loopback Address : An address that sends outgoing signals back to the same computer for testing. Loopback IP address is 127.0.0.1

Ports : Many incoming and outgoing connections can arrive and leave a single computer at the same time. To keep correct track of all the connections, the computer lets them in and out through different ports, according to the service they are asking or giving.

Internet names : These names have the special form subdomain. domain.extension, where the extension usually indicates the network type or nationality:

- .eu for Europe, .it for Italy, .ge for Germany, etc.
- .com formerly for US commercial companies, now for every company;

The domain is chosen by the network's owner to reflect the company name or to be easily remembered by web surfers.

The Domain Name Server (DNS) takes care of converting every Internet name of the corresponding IP number.

Communication programs : Inside a computer network many communication programs are installed on Intranet computers to connect to the Internet or even to internal computers.

TYPES OF INTERNET CONNECTION

(i) Dialup Connection : The connection of Internet by using existing / new telephone line connection. It requires the MODEM to connect to computer. It is slow in speed, so it is not broad band connection.

(ii) DSL Connection : It stands for Digital subscriber line (not link) that requires an existing / new telephone line connection. It provides high speed internet access, compared to dial up connection. It is a type of broadband connection.

(iii) Broad band Connection : It does not require a telephone line connection. It provides high speed data access to Internet. Routers are used in this connection to clear the data traffic and provide high speed access.

(iv) WIFI : Wireless Fidelity. It is a Wireless connection to network. It is limited to a small distance only providing high speed internet connection.

(v) WIMAX : World wide Interoperability for microwave Access. When compared to wifi, it has capacity to cover larger distance.

Example : If suppose, wifi is connected up to 500 metres, wimax can be connected upto 2 kilometres.

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Both are used for connecting to Internet only.

Internet connections : There are many different ways to connect to the Internet, divided by the physical mean of connection: the telephone cable, a dedicated cable or electromagnetic signals.

Names	Equipment	Subscrip-tion	Use cost	Effective speed	Notes
PSTN Plain Standard Telephone Network dial up	telephone modem	free	telephone call	56 kbps	Telephone is busy during connection
ISDN Integrated Service digital Network ADSL Asymmetric Digital Subscriber Line	ISDN telephone ISDN modem telephone ADSL mo-dem	free necessary free	telephone call free time free	128 bps 500 kbps in upload 1-20 mbps download	Telephone is busy during full speed connection (Speed depends on subscription fee and network traffic)
T3E3/T4 E4	special cable	necessary	free	40/300	
GPRS General Pocket Radio Service	GSM cellular phone	free	traffic fee	100 kbps	
UMTS Universal Mobile Telecummu-nications system	UMTS Cellular phone	free	traffic fee	3-7 Mbps	Speed depend strongly on environ-ment
Wireless Wi-Fi	wireless card	depends on the LAN policy	free	70 Mbps	Speed depends on wireless generation
WiMax	antenna in line of sight	still to go on the market		2 Mbps	Speed depends strongly with dis-tance

Web Browser :

Web Browser is a software that is used to view the web pages.

Web browser : A web browser is a client program to navigate the WWW and retrieve web pages. Well known being Safari, the browser for Mac OS X, and Opera, a freeware software which works on many cellular phones.

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LOGIN : The process of authentication for connecting to Internet by providing user name and password.

Authentication : The process of verifying valid username and password, that is given by the user.

Licence / End user Agreement : Accepting the terms and conditions of any software / licencing authority to use their products for personal use.

Web Site : The collection of web pages in a single place.

Homepage : The first page of the website.

URL : It is word based unique address of IP address.

HTML : Hypertext means text, image, audio and video etc.,

Web pages are saved and viewed in HTML format only

Domains : The host / server of the website category is called domain

Note : www developed by Tim Berners Lee

World Wide Web : The World Wide Web (WWW), born in mid 90s, is a huge collection of electronic documents, which are accessible from the Internet using a web browser.

Upload : The process of data transmission from client / local system to the server.

Download: The process of receiving data from server to local system.

Attachment : The paper, music, video file sent as a soft copy. It can modified at receiver side is called Attachment.

TYPES OF WEBSITES :

(i) Static website : The webpages or information on website is not changed from /for long time.

(ii) Dynamic website : The webpages or information on website is changed from / for regular time / daily.

SERVICES OF INTERNET :

(1) E - Mail : Electronic mail is similar to writing a letter to receiptents but transmitted in electronic medium (Invented by Ray Tomlinson in 1971)

ASCII Code : (American standard code for Information Interchange) : The text in mail is first converted from normal text to ASCII code (not ANSI Code) with each character in ASCII code is 1 Byte or 8 Bits of data.

Mail reader : It is a client program to send and retrieve e-mails. It runs directly on the user's computer.

Protocols for E-mail :

To communicate with the mailserver, the mail reader uses special languages, called protocols:

- Post Office Protocol (POP) to retrieve or receive e-mails at port 110, POP3 is the version 3 protocol being in use these days. G-Mail is a Google product.
- Simple Mail Transfer Protocol (SMTP) to send e-mails at port 25,
- Internet Mail Access Protocol (IMAP) is the more modern protocol, which will become popular in the next years, to retrieve and send e-mails.

Voice over IP programs :

Voice over IP (VoIP) programs are able to use the computer connection as a substitute for standard telephone. Equipped with either microphone and headphones or with a real telephone-like device, the user can send his voice through the Internet to remote computers or even to real remote telephones, thus saving on telephone bills.

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Other communication programs : Other commonly used communications programs are : Chat programs, File transfer protocol, telnet and peer to peer programs.

(2) Video Conferencing : The service provided by Internet, for meeting people and talk directly in video conference from different places around the world. It Requires camera and also Head set (optional). Teleconferencing is also electronic meeting (Audio chat) provided by networking.

Ex: Skype, Gizmo

(3) Social Networking : The way of connecting people around the world at one place to share their views and ideas through Internet.

Ex : Facebook orkut Twitter Google +
Linked In Badoo meetup Ning

Services Provided by Internet :

(1) E- Commerce
(2) M-Commerce
(3) Internet Banking

(1) E-Commerce : The online shopping (Both selling and purchasing) of products and services is called E- commerce.

(2) M- Commerce : The store that combines shoping and physical presence is called Mobile Commerce. Here the physical presence is mandatory. It is also called mobile commerce.

(3) Internet Banking : The facility provided by banks to do online transactions through computers and Internet facility on line transactions refers to

Virtual Keypad : The key board provided by specific websites such as Online banking websites to reduce the risk of key stroke threats while entering username and Password. Virtual keypad is visible on screen only.

Cookies : These are the components that store the web history performed by user on specific computer.

Bookmark : The web pages saved by users to see even when there is no Internet connectivity also.

Favourites : The frequently opening URL (websites) can be saved here.

TYPES OF SERVERS ON INTERNET :

(i) Web server : The program that uses client / server model and WWW with HTTP.

(ii) Client server architecture : It is network architecture which separates the client from server.

(iii) Proxy server : It provides the webpages from servers to clients. It also serves as firewall to prevent from unauthorised access.

WAP : Wireless Application Protocol. It is used as web browser for small mobile devices.

Ethernet Cables : It is the IEEE standard cable, used for connecting a system to the network point. It is hard wired device connected to CPU for network connection. It carries / allows 48 bits address length.

NETWORKING DEVICES

The devices that are used as mediators in connecting to the network are called Networking devices.

(i) Bridge : It connects multiple network segments along with data link layer. It works on data link layer.

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(ii) Switch : The device splits the network traffic and sends it to different destinations (within LAN). It works on Data link Layer, uses MAC address to transmit data.

(iii) Repeater : The device that regenerate digital signals received while transmitting from one part to another. It works in Physical Layer.

(iv) Router : The device used in data traffic clearance in Internet Protocol (connects 2 different networks). It is the device used in Broad band Internet Connection. It works in Network Layer to connect internet.

(v) Gateway : The device setting at a network node for interfacing with another network that uses different protocols. It works on all 4 layers from Transport Layer to Application Layer. The only device that works in 4 layers is Gateway.

(vi) Brouter : Hybrid device that combines features of Bridge and Router.

Connecting Devices :

(i) MODEM : It is combination of both modulator and Demodulator. It is used in Dial -up connection along with the telephone line.

(ii) HUB : The connecting device used in connecting ethernet segments in LAN'S. Hub can be :

(a) Active Hub : The signal is Amplified, so they work as Repeaters. So it requires power supply.

(b) Passive Hub : The signal is forwarded as it is. So it does not require power supply.

Digital Banking : It is different from online Banking. The transactions / Bill Payments using mobile phones is called digital Banking. Internet and Telephone both may be used in digital Banking.

Junk Mail : The Advertisement mails sent out by specific sites for which, we have given our email Id.

Meta Search Engine : A meta search engine is a search tool that sends user requests to several other search engines.

Hot Keys : A hot key is a key or a combination of keys on a computer keyboard that, when pressed at one time performs a task more quickly than by using an input device.

COMPUTER VIRUS

VIRUS (Vital Information Resource Under Seize) : It is a program designed to spread itself and infects executable files / hard disk and makes virus copies itself. Virus attacks computer and corrupts / removes the data.

1. It arrives on the computer through e-mail attachments, downloaded files, CDs and floppy disks or directly from the Intranet.
2. As soon as the user mistakenly runs it, the virus orders the computer to run itself every time the computer is turned on, thus assuring its survival.
3. It starts duplicating itself, infecting other files.
4. Most viruses are programmed to do damage to the computer and to the user, altering or deleting files, sending e-mails with user's personal data, preventing firewalls and antiviruses from running, or turning the computer off.

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Antivirus The antivirus basically has three possible different actions:

- it can scan all the storage devices for viruses. If a virus is found, it tries to remove it and to repair damaged files.
- it can scan a single file or an entire directory for viruses. If there is an infected file, it tries to delete the virus and repair it.
- it is running. In this case, whenever a virus or a suspect file is run, the antivirus prevents it from running and warns the user.

TYPES OF VIRUS

(i) Boot Sector Virus : The virus persent in the boot devices. Brain virus is an boot sector virus.

(ii) Worm : The self replicating computer program that always harm the network.

(iii) Trojan Horse : The harmful virus, which is a written program that harms the computer. Creeper is the trojan horse virus.

(iv) Bomb : The virus which has some payload to destroy files on computer.

Logic Bomb : It occurs when user of computer takes action that triggers the bomb. It requires the human action.

Time Bomb : It occurs to blast payload in computer at specific time or data written in program. It does not require human action.

(v) Micro virus : It spreads in only application software.

(vi) Spyware : The malicious software that collects information about users without their knowledge.

(vii) Malware : It is a superset of virus, worms, trojan horses, root kits and spyware etc.

SECURITY THREATS

Computer security : Being connected to the Internet means giving anybody access to the computer.

Every user who has access to personal data protected by privacy must take care of there procedures, in particular user :

- must be authenticated by a personal username and a password.
- has its own permissions, limited only to the data he needs for his work.
- must receive specific training to be able to use their authentication and to be aware of their responsibilities, duties and the possible dangers;

Encryption : Encryption is a text masking technique, derived for military use, which transforms information in such a way that it may be correctly read only with a key. It uses two keys, one for encrypting, usually known only to one computer or person, and one for decrypting, usually known by all the computers or people which legitimately may read the information.

Passwords : On the Intranet the user is identified only by his username, known to everybody and his password, having minimum of eight characters known only to him. The password is what makes an unknown person an authenticated user, with all his privileges and his identity's responsibilities.

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Token key : The token key is a modern password system which consists of a very small electronic device which displays a password changing every few seconds. The system is perfectly time-aligned with the token key and each password is accepted only if entered in those seconds. Therefore, even if a password is intercepted or guessed, it expires after a few seconds.

(i) Phishing / Spoofing : The attempts made fraudently to acquire sensitive information such as passwords, credit card details etc by acting as a trust worthy person. Attempts here called as phishing trips.

(ii) Hacker : A person who uses his or her expertise to gain access to other people's computers to get information illegally or do damage is called Hacker.

- Cyber Crime : The theft or frauds through online (Internet) is called cyber crime.
- Malicious Hacker : The Hacker who are involved in the hacking process with intension.
- Non - malicious Hacker : The Hacker who involved in the hacking process with no knowledge and for time pass only.

(iv) Spam : It is the unsolicited and bulk mails in the e-mail.

- This is not a security threat.

Ethical Hacking : The hacking done by department to retrieve the status of thief or criminal.

PREVENTION TECHNIQUES

(i) Digital Signatures :

The private key is maintained with Encryption and public key maintained at Decryption. All the users can not change data, but they can only access data in data base.

(ii) Ceaser cipher : It is the method of shifting every plain text message replaced with n^{th} successive Alphabet text that is converted into an another alphabet.

(iii) Firewall : It is a software or hardware based device to permit or deny network transmission based on set of rules and used to protect network from unauthorized access.

E-MAILS

Spam : Spam messages are unsolicited unwanted bulk e-mails.

Navigation : Navigation is the second most dangerous Internet activity. It has more or less the same dangers as emails: the user's computer can get viruses if he does not run an antivirus before opening downloaded files.

The other security problem while navigating is data interception. When connecting to a website, the user's data travels long distances, passing through a large number of computers.

DATA AND INFORMATION

The "brain" of the computer, the CPU, consists primarily of several million tiny electronic switches, called transistors.

A computer only appears to understand information because it contains so many transistors and operates at such phenomenal speeds, assembling its individual on/off/switches into matters that are meaningful to us.

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The computer converts the data into information by processing it in some way.

Computer And Data Type :

There are two basic types of data, which are stored and processed by the computer. They are : characters and numbers. But to a computer everything is number.

The characters and numbers are assigned different values by the computers. However, the output from the computer, must be in the form that is understood by the users. Thus the computer translates those values into the form understandable by the normal users, which is again natural language consisting of numbers and characters. This constitutes. External Data Representation. On the other hand, the values used by the computer to store and process the data is Internal Data Representation.

TEXT CODES :

The varied codes used for the representation of the output data include three systems.

EBCDIC :

The Binary Coded Decimal (BCD) system was defined by IBM for one of its initial computers. It was one of the first complete systems to represent the symbols with bits. BCD code consisted of 6-bit codes, which allowed maximum of 64 possible systems.

ASCII :

ASCII stands for American Standard Code for Information Interchange. Currently, the ASCII character set is 7-bit code in common use.

The characters 0 to 31 are control characters, from 32 to 64 are special characters, 65 to 90 are uppercase alphabets, 97 to 122 are lowercase alphabets and 123 to 127 for some common symbols.

UNICODE :

A new standard for data representation, called Unicode Worldwide Character Standard, provides 2 bytes that is 16 bits to represent each symbol. It means that the range could be anything up to 65, 536 different characters or symbols as all the characters and symbols of the world can have the same standard and thus facilitate the interchanging of the data and programs written in any language, without any special programs.

NUMBER SYSTEM :

The various types of number systems and also the transformational rules to interconvert them. (i.e., external representation of data into internal data and vice versa)

DECIMAL SYSTEM

The characters and strings of characters are represented internally in a computer. Decimal digits are also considered as characters and codes are assigned to them. These codes for digits are primarily used when digits are used merely as symbols with no "value" assigned to them.

BINARY SYSTEM

If a number system has only two symbols then its base is 2. Such a system is called binary system. Numbers in this system are strings of bits. For example :

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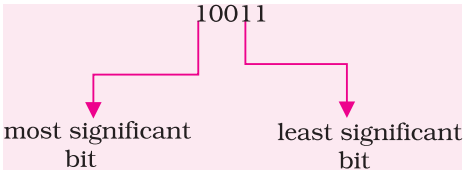
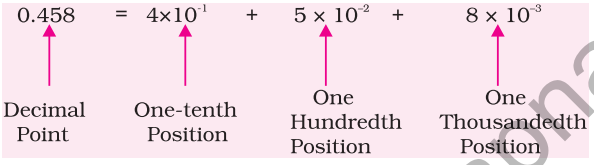


The right most bit is called LEAST SIGNIFICANT BIT and the left most bit is called the MOST SIGNIFICANT BIT. The weights assigned to the bits are the powers of 2 as $2^0=1$, $2^1 = 2$, $2^2 = 4$, $2^3= 8$, $2^4= 16$, etc.

REPRESENTATION OF FRACTION

Decimal fractions are interpreted as :



Point to be noted is that the negative powers are used as the weights to multiply the digits in the fractional part of the number.

A binary fraction is represented by a string of 1's and 0's and 0's on the right of a binary point.

HEXADECIMAL REPRESENTATION OF NUMBERS

The binary equivalent of a ten digit decimal number is be 32 bits long. Writing such long strings of 0's and 1's are a very cumbersome and error prone task. This problem is solved to a great extent by using the hexadecimal system, which uses 16 as a base. There are sixteen symbols used by this system viz. : 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F. Here the symbols A, B, ...,F are used to represent the numbers. We need only 4 bits to represent a hexadecimal digit. The table below gives the hexadecimal-system's symbols, their decimal and binary equivalents.

Binary number	Hexadecimal equivalent	Decimal equivalent	Binary number	Hexadecimal number	Decimal equivalent
0000	0	0	1000	8	8
0001	1	1	1001	9	9
0010	2	2	1010	A	10
0011	3	3	1011	B	11
0100	4	4	1100	C	12
0101	5	5	1101	D	13
0110	6	6	1110	E	14
0111	7	7	1111	F	15

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Binary number (1101111000101001) is converted into hexadecimal equivalent by first making groups of four bits starting from the least significant digit and proceeding towards the most significant digits.

Binary Number :	0001	1101	1100	1001	0100
	↑	↑	↑	↑	↑
Hexadecimal Number :	1	D	C	9	4

CONVERSIONS

All the number systems binary and hexadecimal can be inter-converted into one other. The set of rules to convert them are :

Decimal to Other Number Systems :

POWER METHOD

(a) Writing the powers of the radix till it is less than the number to be converted.
(b) Subtracting the highest number, which is obtained by raising the powers of the radix from the number, which is to be converted.
(c) Obtaining the remainder say R.
(d) Subtracting the next highest number from this remainder.
(e) Repeating the process till the remainder is zero.
(f) Now multiplying the powers, which have been used with one and multiplying the powers by zero which have not been used.

REMAINDER METHOD

This is the method commonly used for the conversions from decimal number system to the binary number system. The conversion is carried out in the following order: divide the given number (decimal system) by the radix of the proposed system (in which the number has to be converted). Note down the remainder.

Now the quotient will again be divided by the radix and the remainder will be noted down.

The procedure goes on till zero comes as quotient.

FRACTIONS

The fractional decimal numbers can be converted to binary numbers by following the steps given below:

1. Multiply the radix of the proposed system with the fraction to be converted.
2. Note down the resulting integer (if any) otherwise put down zero in that place.
3. Repeat the multiplication with the resulting fraction.
4. Keep repeating the procedure till the fraction vanishes or you encounter the recursive fractions.

BINARY SYSTEM TO OTHER NUMBER SYSTEMS :

Binary to Decimal Number System

Binary number can be converted to decimal number system by multiplying each binary digit with its respective position weight and then adding all the results.

BINARY TO DECIMAL (FRACTION)

The binary fractions are converted to the decimal number systems by multiplying each digit by their respective position weights (that is the negative powers of the base 2) and then adding them together.

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Thus the decimal equivalent of $(1011.11011)_2$ is $(11.84375)_{10}$

ARITHMETIC OPERATION IN BINARY SYSTEMS

All the arithmetic operations (addition, subtraction, multiplication and division) in binary system are performed in the same way as in decimal number system. All the four arithmetic operations are described as below:

Addition

Rules for carrying out binary Additions are:

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 0 with one (1) carry over.

Example

1. For adding 101110_2 and 111101_2

Binary	Decimal
101110	46
111101	61
1101011	107

Thus, 1101011 in binary system is equivalent to 107 in decimal system.

SUBTRACTION

Rules for carrying out binary subtraction are :

1. 0 - 0 = 0
2. 0 - 1 = 1 with one borrow
3. 1 - 0 = 1
4. 1 - 1 = 0

Examples

1. For subtracting 101110 from 111101_2

Binary	Decimal
111101	61
101110	46
001111	15

Thus, 001111 in binary system is equivalent to 15 in decimal system.

Multiplication

The rules for the multiplication are:

$0 \times 0 = 0$
$0 \times 1 = 0$
$1 \times 1 = 1$

Example

Multiplying 111101 with 1110

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Binary	Decimal
111101	61
1110	14
000000	244
111101×	61×
111101××	854
111101×××	
1101010110	

Division

The rules for division are same in binary system as those in decimal number system.

```
110 | 100100 | 0110
      110
      0110
        110
          ×
```

This is same as division of decimal 36 with 6.

□□□

PAYMENT SYSTEMS AND ELECTRONIC BANKING

The growth of technology has changed payment systems the world over during the past two decades.The introduction of the automated teller machines (ATMs) and the plastic cards has given the banking customers the facility of round the clock (24 hours) banking.

Automated Teller Machines (ATMs) : Automated Teller Machines (ATMs) are primarily used for performing some of the banking functions such as the withdrawal of cash or the deposit of cash/cheque, etc., by using an ATM card. The committee headed by Dr. C. Rangarajan recommended the setting up of ATMs in India.

Convenience of ATMs

To the Customers

(a) 24 × 7 access availability
(b) Less time for transactions (less queue)
(c) Privacy in transactions
(d) Any branch/anywhere banking enabled
(e) Acceptability of card across multiple bank ATMs, even foreign tourists can access Maestro/VISA ATMs

To the Bank : Cost of setting up ATMs is lower than setting up a branch with Less hassle in handling cash.

ATM Models in India

On line : When the ATM is connected to the bank's database and provides online real time access to the customers accounts, it is said to be 'online.' Normally, there is a daily limit of withdrawal set by the bank. This limit is monitored by the ATM switch centre.

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Offline : When an ATM is not connected to bank's database, it is stated to be 'offline.' In this mode, withdrawals are permitted up to a pre-fixed limit only, irrespective of the balance available in customers' accounts.

Stand-alone : When an ATM is not connected to any ATM network, it is said to be 'stand-alone'. In this case, transactions at an ATM are restricted to customers of the ATM branch and its link branches.

Networked : When ATMs are connected to an ATM network, they are said to be 'networked'. The advantage of networked ATMs is that cardholders can use their ATM cards at any of the networked-ATMs. This in effect permits 'anywhere anytime' banking.

Cash Dispenser (CD) : Cash dispenser is a pruned down version of the ATM. CD is an ATM without a depository and is intended to serve the customers for making cash withdrawals only.

Networking of ATMs : Indian Banks' Association (IBA) was the first to set up a shared payment network system (SPNS) or SWADHAN network of ATMs of its member banks in Mumbai. The network went live on 1 February, 1997. The objective behind the SWADHAN network is to provide 24 hours, 7 days a week electronic banking service to the customer of a member bank any where in the city of Mumbai. The customer is free to conduct transactions at the ATMs of any of the member banks located in the neighbourhood.

HWAK (The Intelligent Auto-teller and Netware Management System) : Intelligent auto-teller systems are a special breed of auto-teller machines capable of thinking for themselves, that means they are fast, impose less demands on your banking systems and serve the customers more like a personal banker than less sophisticated auto teller systems. HWAK provides unsurpassed service even without benefit of a reliable communication network.

PERSONAL IDENTIFICATION NUMBER (PIN)

A magnetic strip is fixed on the back of the cards. A PIN 'Personal Identification Number' is a combination of numerical digits only is similar to the password that a user of a computer has to give when he/she wants to use it.

ELECTROMAGNETIC CARDS

Credit Cards : Generally, a bank enters into an agreement with its customer and issues the customer a credit card. It has the name and the account number of the holder embossed on it. In addition, the date up to which the card is valid and a specimen signature panel on the reverse.

Many card issuers, being banks, also allow withdrawals of cash for emergency purposes and levy a service fee for such withdrawals. Many banks also have credit cards which double up as ATM cards.

There are different types of credit cards :

Charge Card : In charge cards, transactions are accumulated over a period of time, before the total amount charged, i.e. debited to the account.

Credit Card : It's like charge card with the difference between the credit and charge card is that in case of charge card, the amount becomes payable immediately on the debit to the account.

Debit Cards : A debit card acts like a credit card, the difference being that funds are immediately taken from the-cardholders accounts.

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Smart Cards : The Smart Card are two main types of smart cards: Intelligent memory chip and micro-processor cards.

Memory smart cards have been around for several years. They are being used in pay phones, identification, access control, voting and other applications.

Processor smart cards are the most advanced and are ideally suited for banking and financial applications where reuse of the card is allowed. These cards have a built-in memory and the processor along with an operating system. They perform the financial operations. with an intelligent built-in, they can protect themselves against fraudulent operations.

Terminal Requirement : A special terminal must be used to read and update the smart card, with the following features:

A smart card reader must be available that meets ISO specifications and can read and write the card.

A secure pin pad must be provided, which allows the user to enter the PIN and have it checked by the smart card. The pin pad would have to store the secret keys for the application and must be designed so that it is impossible to extract these keys under any circumstances.

Security Advantages : The security level has even been certified by independent and competent authorities. Unlike a conventional magnetic strip card, which can be easily erased or copied, smart card has a protected and much larger memory. Smart cards also have confidential memory zones holding secret user information.

The Future is Bright : The future of the smart card in the banking and the financial sector is very bright and it is evident that leading players in electronic funds transfer have already realised this. Earlier in 1993, NATWest Bank of the UK announced its Mondex system, based on smart cards. Visa and Master Card have also joined hands with Europe's largest ATM network, Europay to set standards for smart card-based electronic fund transfer systems. In India too, there are moves afoot to introduce smart card-based personal banking.

Member Card : This is used exclusively by members of a club or a chain of hotels. The cards are for use in their hotels only. Similarly, there are many other types of cards where the usage is exclusive to the members of a group or establishment.

The advantages of credit card system to the concerned parties are as under:

To the cardholder :

(a) It is convenient for him to carry a credit card in his wallet and make trouble-free travel or purchase. It allows him to draw cash too

(b) It inculcates a sense of financial discipline in him

(c) It provides a proof of purchase through banking channels to strengthen his position in case of disputes with sellers, etc.

Electronic card :

(a) Card is accepted through electronic EDC (Electronic Data Capture) machines. Validity of the card and credit limit is verified online and approval is by the merchant online

(b) Interchange fee in this mode is 1.10 per cent per month. Here, the merchant should have a telephone facility.

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MULTIPLE PINS

Apart from multiple PIN facility, other security features are also available with the smart card, which are as under:

Dynamic signature verification : It traces the way in which a signature is written - the dynamic signature tablet automatically verifies whether the signature is genuine or not.

Fingerprint verification : It is used to identify whether the user of the smart card is genuine or not by electronically scanning fingerprint ridges.

Voice recognition systems : It uses a computer which is programmed to recognise different voices and compares the voice with the recorded original.

Retinal pattern verification : The pattern of the blood vessels on the retina of the human eye is a unique physical characteristic; the retina is scanned using a low intensity infrared beam to ascertain person's identification.

Visual recognition : It is possible to digitise a picture of a person and store it in a smart card memory. The picture, usually obtained by a scanning video camera, is digitised and then compressed to enable it to be stored in the smart card. These days, this system is becoming very popular.

ELECTRONIC PURSE

The card has space for several 'electronic purses', each for the storage of an amount. These can be used for different types of accounts of the user. In addition, there is space for user data such as address, the branch where the user has his account, and even the last thirty to fifty transactions.

The advantages of the processor smart card are: security, reliability and longer life. This card can be used for financial systems in many developed countries.

INTERNET BANKING

With the popularity of PCs and easy access to Internet and World Wide Web (WWW), banks increasingly use internet as a channel for receiving instructions and delivering their products and services to their customers. This form of banking is generally referred to as Internet Banking, although the range of products and services offered by different banks vary widely both in their content and sophistication.

Some of the distinctive features of i-banking are:

(i) It removes the traditional geographical barriers as it could reach out to customers of different countries/legal jurisdiction.

(ii) It has added a new dimension to different kinds of risks traditionally associated with banking. heightening some of them and throwing new risk control challenges and risk perceptions.

(iii) Security of banking transactions, validity of electronic contract, customers' privacy, etc.. which have always been matters of concern.

(iv) It poses a strategic risk of loss of business to those banks who do not respond in time to this new technology.

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MOBILE BANKING

Mobile Banking comes with features like 128 bit encryption and open Internet technology, i.e. it is not dependent on any specific service provider and the handset company. The service is free of charge.

ELECTRONIC COMMERCE (E-COMMERCE)

E-commerce is a digital preference in use.

E-commerce translates include a higher degree of personalisation, round-the-clock advantage, fast and flexible execution, immediate customer reaction, and reduction in operating cost.

CHEQUE TRUNCATION

Cheque truncation - Definition : A cheque truncation is defined by the new Section 6(b) of Negotiable Instruments Act as 'a cheque which is truncated during the course of a clearing cycle, either by the Clearing House or by the bank, whether paying or receiving payment, immediately on generation of an electronic image for transmission, substituting the further physical movement of the cheque in writing.'

Ways in which truncation can be done

1. Using MICR data: MICR cheques have the cheque number, city, bank and branch numbers, and transaction code pre-coded. Abroad, even the account number of the customer is precoded. During encoding at the collecting bank, the amount, as well as the payee's name, is inserted in the MICR line. The entire MICR line is then captured electronically. The electronic information is then exchanged with other for clearing (Inter Bank Data Exchange or IBDE). The cheques do not move any further.
2. Using image processing : Image processing, is the latest document handling system. Cheque image processing involves scanning of both sides of the cheque and storing the image in digital form. The cheque itself is moved to some offsite storage and the image is used for further processing.

Advantages

Cheque truncation truncates or stops the flow of cheques through the banking system. Further processing of cheque is done with the electronic information rather than paper (i.e. the cheque itself).

Truncation can occur at the branch in which the customer deposits the cheque, i.e. the collecting branch. The collecting branch truncates the cheque and sends the electronic data to the clearing house or directly to the paying branch.

ROLE OF TECHNOLOGY UPGRADATION AND ITS IMPACT ON BANKS

Trends in Technology Developments : The advancements in software tools, computer hardware and telecommunications have shifted the focus of the banks towards computerisation from data processing to information services.

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Data Warehousing and Data Mining :

Data Warehousing : Data warehousing is the emerging trend, in the corporate world including banks, which has been made possible by the application of information technology. Databases known as data warehouses are designed, wherein data from herterogeneous sources is stored to generate critical information for the decision support systems. The main characteristics of the data stored in a data warehouse are :

Electronic Mail : Electronic mail provides nearly instantaneous communication between different users, regardless of the system they are using at their location, for any type of information imaginable. Electronic mail has made the concept of the paperless office a reality and many offices now use it extensively for interoffice and intra-office correspondence. (Green Economy).

In banks, electronic mail is used for correspondence between departments and offices and has dramatically reduced the time taken from the use of the previous physical delivery methods.

Management Information Systems (MIS) : The concept of MIS places particular emphasis on the availability of data and the ease, with which it can be analysed and turned into meaningful information for managerial decision making. Thus, the key element in any MIS is the transformation of data into information. Another factor that assumes significance is the timeliness of information, lest it loses its significance. As such, the system has to be such which furnishes the management with current information.

Computer-based Information Systems : The computer-based information systems offer following advantages:

1. Data is consistent and hence, the processed information is more accurate and relevant for decision making.
2. Data redundancy is minimised, reducing a lot of labour in data reporting.
3. The computer-based information systems are more flexible and can suitably be modified with ease to match the changing requirements.

These computerised systems not only help in the generation of a large number of statutory and control returns, but also help in generating a wealth of information to aid in decision making.

ELECTROTECNOLOGICAL DEVELOPMENTS AND CUSTOMER ASPIRATIONS

Today, the customers are demanding fast, accurate and reliable services. The customers expect a reasonably high standard of services. The absorption of technology, therefore, becomes inevitable for the banks to enable them to respond to customers needs at all times and at competitive prices. In the changed socio-economic conditions, the customers, individual or corporate, no longer want to be restrained by the physical place where their funds and information are stored and wish the banking facility to come to their home/business place rather than in branches of banks. This has given rise to the concept of 'Anywhere Banking' facility which offers access to banking services at a place and time convenient to the customers.

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IMPACT ON HUMAN RESOURCES

The technology has also brought about a visible impact, as discussed below, on the human resources, which is the most vital component in the banking business.

1. The foremost impact of technology on the existing manpower is manifested in the resistance to the new systems. Such resistance is not unique to the banking industry, but stems from the basic instinct in human beings to view any change with an element of suspicion. The fear of change gives rise to anxieties, inhibitions and scepticism, which can be overcome only with the spread of awareness at all levels. These fears may be described as follows:

   (i) Job content : Fears, such as whether the technology will mean losing ones' expertise, or will the personal skills will be adequate to meet the challenges of the new job, or whether it would mean a change in the way one used to handle a job.

   (ii) Job security : Fears whether the change will mean a loss of the job itself, or whether it would be possible to retrain oneself in the new scheme of things, or would it mean a transfer from the existing work place, or whether the new computer literate employees will have better job profiles or whether it would mean a hindrance in the career growth,

   (iii) Authority dilution : Fears such as whether the change in job requirements would mean erosion in one's authority within the organisation, and would it be possible to continue commanding respect.

2. Technology, when introduced in a planned manner, results in enhanced productivity with better placement of employees. With the increased use of information technology, there is an ever increasing demand of the specialised personnel in the fields of IT management.

3. Another impact of IT on human resources is the high turnover rate of computer-skilled manpower. This may necessitate the banks to formulate their own manpower policies to retain these professionals within the organisations.

TRAINING NEEDS

The most important element in this process involves the organisation-wise training for attitudinal changes and skill developments, commensurate with the requirements of changed role of individuals. Dissemination of knowledge about the new developments in technology and its application is also required for the upgradation of skill levels.

The changes in attitudes can be brought about if adequate information is provided in time on the capabilities and limitations of the information technology tools. It can be done through the process of training of staff.

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